GRIDCO
Empowering Odisha

CDRI
Coalition for Disaster Resilient Infrastructure

Codes, Standards and Technological Innovations for Infrastructure Design

Component-II Task-II

Disaster Resilient Power Systems for Odisha

Power Research and Development Consultants Private Limited

KPMG Advisory Services Private Limited

TARU Leading Edge Private Limited

Foreword

Power infrastructure and a stable electricity connection is an essential enabler of development. It supports homes, businesses, schools, hospitals, and the supply of other utilities. The introduction of smart grid technologies, bolstering renewable energy sources, and enhancing load efficiency is imperative for achieving global climate commitments.

Escalating climate risks present a challenge to this essential infrastructure and its interconnected systems. Power infrastructure in coastal regions is particularly vulnerable given the magnitude of climate intensified extreme weather events in these regions.

India has a coastline stretching over 7,500 kilometres. Its coastal areas are home to more than 260 million inhabitants. Cyclones like Fani (2019), Gaja (2018), and Hudhud (2014), which were accompanied by severe flooding, caused extensive damage to lives and livelihoods across the coastal states of Odisha, Andhra Pradesh, Tamil Nadu, and Kerala.

In response, India has become a leader in building resilience in coastal areas. Improved disaster preparedness, early warning systems, and well-executed evacuation strategies, have played a pivotal role in safeguarding vulnerable populations.

Odisha's experiences in recovering quickly from various disaster events offer compelling evidence for the development of resilient power infrastructure. The state became the first state in India to establish a disaster management authority in 1999 after the Super Cyclone, even before the establishment of the National Disaster Management Authority (NDMA) in 2005. It was also the first Indian state to create an early warning system for disseminating critical disaster-related information to the very last mile. Odisha State Disaster Management Authority has utilized the best technical expertise for building over 800 multi-purpose cyclone shelters together with evacuation roads along the state's entire coastline. Odisha's success in bringing down the casualty to double digits and putting in place robust mechanisms for risk-informed decision-making is a significant achievement.

In support of these efforts, recognizing the particular importance of power infrastructure, and to develop evidence that can be shared with other vulnerable regions, CDRI's study "Disaster Resilient Power Systems for Odisha" has aimed at strengthening the power infrastructure.

This work has identified key challenges and best practices within the Transmission and Distribution (T&D) sector at the subnational level. To understand vulnerabilities related to the T&D infrastructure system along its entire 480 km of coastline, 16 indicators were identified ranging from commissioning year to asset failure history. Recommended actions, including investment options to strengthen resilience of the T&D infrastructure, were prepared accordingly. The study serves as a vital resource for stakeholders in the power sector.

On behalf of CDRI, I express sincere gratitude to all stakeholders from the Government of Odisha, including GRIDCO Ltd, for their invaluable contributions to the report's methodology and policy recommendations for the short, medium, and long term. I would also like to extend my sincere appreciation for NDMA's support throughout the entire effort. Collaboration with Taru Leading Edge, Power Research and Development Consultants (PRDC), and KPMG - India has been instrumental in preparing this report, which serves as an indispensable tool for policymakers, practitioners, manufacturers, and other stakeholders in the power sector.

CDRI believes that the resilience of the power sector to extreme weather events is pivotal in safeguarding the lives and livelihoods of millions, particularly those in vulnerable regions. We are committed to take the lessons learned in Odisha and expand similar work to support coastal regions around the world.

Amit Prothi
Director General, CDRI
New Delhi, India, June 2024

Foreword

Global energy consumption is steadily increasing annually, with an anticipated 48 percent growth over the next two decades, driven by the exponential rise in global population. In the face of escalating challenges posed by climate change, ensuring resilience in energy systems is imperative for overall development. Given the historical impact of extreme weather events on the state of Odisha, particularly the Transmission and Distribution (T&D) segment, the state has demonstrated remarkable resilience. It has rebounded and recovered by developing innovative adaptation and mitigation strategies in response to periodically changing wind speeds and the looming risk of climate change.

Understanding the socio-economic impact and losses in this regard, this study serves as an essential tool and a precursor at the sub-national, national, and global levels for coastal regions and regions with similar geographies. It provides insights into strategies that can be replicated not only for risk identification and estimation but also for capacity building, knowledge management, and financial preparedness.

This initiative aims to evaluate the climate resilience of Odisha's power infrastructure in a unique way. It will not only help in reshaping the policy landscape and risk-based governance for coastal regions but also provide valuable insights for energy sector practitioners, Original Equipment Manufacturers (OEMs), and regulators. The report details individual unit-level assets, their vulnerabilities, and offers investment options on how to build more resilient transmission and distribution assets. By setting a new standard for resilience initiatives, the study is expected to significantly influence the development of robust and adaptive energy systems, ensuring a sustainable and secure future for all.

I extend my appreciation to the Coalition for Disaster Resilient Infrastructure (CDRI) and the project stakeholders for this collaborative effort, which will help enhance the reliability and resilience of the state's power infrastructure. I strongly believe that the report will serve as a benchmark in climate-proofing of energy infrastructure in Odisha.

Principal Secretary to Government
Energy Department,
Government of Odisha

Preface

India is highly vulnerable to various natural hazards such as cyclones, tsunamis, earthquakes and floods, among other catastrophes. Approximately 12 percent of the nation's land area is prone to flooding and river erosion, while more than 58 percent is vulnerable to earthquakes of moderate to very high intensity (MHA, 2015). The susceptibility to cyclones and tsunamis affects approximately 76 percent of the coastline, particularly impacting the eastern coastal states of Tamil Nadu, Andhra Pradesh, Odisha and West Bengal (CEA, 2021). Climate change has increased the frequency and severity of these catastrophic events, wreaking havoc on the economy and society.

Odisha, with a 480-km coastline along the Bay of Bengal, often faces severe impacts from these disasters. Power infrastructure is one of the most severely affected sectors in the region. Large-scale damage to the state's transmission and distribution (T&D) infrastructure due to cyclones is common, leading to extended power supply outages in affected areas. Additionally, floods in Odisha are another major obstacle to the electricity infrastructure, making it impossible to operate and maintain during high rains and severe waterlogging. Between 1996 and 2018, Odisha experienced 13 years of floods and five years of cyclones (Sethi, 2019).

In light of the profound consequences that climate change and disasters have on power infrastructure, the National Disaster Management Authority (NDMA) of India convened a meeting in July 2019, inviting all stakeholders involved in developing policy and research at the national level, as well as those involved in building and operating power generation, transmission and distribution infrastructure in Odisha. The meeting discussed the power sector's damages and losses and brainstormed a road map for creating disaster- and climate-resilient power infrastructure in Odisha and, by extension, in all high-risk areas of India. The meeting also involved a thorough analysis of the cyclone's impact on the power infrastructure in Odisha, including the technical, organizational and functional factors contributing to significant damage and prolonged power restoration, which was universally acknowledged.

The following action was proposed to move forward: NDMA, in cooperation with relevant stakeholders, would conduct a comprehensive study to improve the power sector's disaster and climate resilience. Drawing from Odisha's experience, the power sector has adopted various innovative approaches to mitigate the effects of cyclones. These innovations, which have been adopted on an on-going basis over the last two decades, need to be systematically documented and disseminated so that the advances made by Odisha may benefit other cyclone-affected states in the country. The Coalition for Disaster Resilient Infrastructure (CDRI) supports NDMA in carrying out this comprehensive assessment of the resilience of power infrastructure in Odisha state.

The study on the resilience of power infrastructure in Odisha is categorized into two distinct phases. Phase I of the study relates to developing and adopting mechanisms for ensuring preparedness, preventing grid collapse, assessing losses, estimating needs and channelling adequate funds to disaster-affected areas promptly for early restoration and resilient recovery and reconstruction. It also includes aspects of community engagement.

The Phase - II study consists of two components, which yield a total of five reports. Component II focus areas include a) Risk Identification and Estimation and b) Codes, Standards, Regulations, Technology and Innovation. Component III focuses on a) Risk-based Governance and Policy Development, b) Capacity Building and Knowledge Management and c) Financial Preparedness and Adaptation.

The Phase-II reports will be a crucial instrument for policymakers to strengthen the power system's resilience, particularly in terms of T&D assets. Additionally, they will aid in evaluating and ranking investments in the power sector among similar geographical areas at every level.

The report **'Strategies for Effective Risk Identification and Estimation'** aims to differentiate the level of susceptibility and the associated risks faced by Odisha's power infrastructure due to disasters. Evaluation has meticulously considered exposure and vulnerabilities, particularly within the various components of the power infrastructure.

The report **'Codes, Standards and Technological Innovations for Infrastructure Design'**, an examines various mechanisms crucial for establishing, enforcing, and regularly updating scientifically informed design standard, codes, and regulations to enhance power infrastructure resilience. This assessment factored in evolving technologies and their changing profiles to ensure efficacy. This study also considers an array of technologies and innovations available to bolster power structure resilience against diverse hazards, emphasizing the tools and technologies that could be integrated to strengthen disaster risk management.

The report **'Risk-Informed Governance and Policy Development'** reflects the need to imbibe strong institutional governance, augmented capacity building and financing for disaster resilience in the power sector. The report further recommends and provides a way forward to build a comprehensive post-disaster need assessment (PDNA) strategy and enhance the techno-regulatory capacity building of Odisha's power infrastructure. It additionally identifies the various gaps and provides plausible interventions to strengthen the resilience in both structural and non-structural aspects of the power sector in the state.

The report **'Capacity Building of Stakeholders for Better Preparedness'** addresses governance and policy structures coupled with capacity-building efforts and makes recommendations for different stakeholders of the state and Energy department. These recommendations aim to facilitate the integration of disaster and climate resilience principles into the planning, operation, maintenance and continuous improvement of power infrastructure in Odisha.

The report **'Financial Preparedness Strategies for Adaptation and Resilience'** states that financial resources are required at various stages to build further disaster-resilient infrastructure, such as disaster prevention, preparedness, response and recovery. This section of the report addresses the financial and adoption strategies.

Acknowledgements

The successful completion of the Disaster Resilient Power Systems study for coastal Odisha stands as a testament to the extensive collaborative and technical effort invested over three years.

The project encompassed thorough desk research, data collection, cleaning, analysis and calculations. The successful accomplishment of this monumental task would not have been possible without the unwavering dedication and hard work of numerous individuals and teams, to whom we express our sincere appreciation and gratitude.

We would like to express our gratitude to Shri Gagan Bihari Swain, Director (F&CA), GRIDCO and his team for their valuable guidance and coordination in collecting relevant data from different stakeholders during the study period. We also appreciate the contributions of OPTCL, TPCODL, TPNODL, TPSODL and OSDMA in providing the required information for the study.

We extend our heartfelt appreciation to our esteemed consultants, M/s Power Research and Development Consultants Private Limited-PRDC, M/s KPMG India and M/s Taru Leading Edge, for their critical contributions to the study.

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Abbreviations

ACA	Additional Central Assistance
ADB	Asian Development Bank
AfDB	African Development Bank
AIS	Air-Insulated Switchgear
CAG	Comptroller and Auditor General
CBDG-DR	Community Development Block Grant – Disaster Recovery
CDRI	Coalition for Disaster Resilient Infrastructure
CEA	Central Energy Authority
CGA	Controller General of Accounts
CHP	Combined Heat and Power
CSR	Corporate Social Responsibility
DDMA	District Disaster Management Authority
DFL	Defined Flood Level
DISCOMs	Distribution Companies
DLNA	Damage, Loss, Needs and Assessment
DM	Disaster Management
DPR	Detailed Project Report
DRC	Distribution Reforms Committee
DRR	Disaster Risk Reduction
EBRD	European Bank for Reconstruction and Development
EOI	Expression of Interest
ERB	Energy Resilience Bond
GIS	Gas-Insulated Substations
GoI	Government of India
GSDP	Gross State Domestic Product
GSS	Grid Substations
GST	Goods and Services Tax
HQ	Headquarters
HUD	Housing and Urban Development

Abbreviations

IADB	Inter-American Development Bank
JICA	Japan International Cooperation Agency
LHV	Lower Heating Value
LT Wires	Low Tension Wires
MDB	Multilateral Development Banks
MH	Major/Minor Heads
NDMA	National Disaster Management Authority
NDMF	National Disaster Mitigation Fund
NDRF	National Disaster Response Force
NDRMF	National Disaster Relief Mitigation Fund
NEA	National Electrification Administration
NJ BPU	New Jersey Board of Public Utilities
NJEDA	New Jersey Economic Development Authority
OM	Operation & Maintenance
OPSEAP	Odisha Power Sector Emergency Assistance Project
OPTCL	Odisha Power Transmission Corporation Limited
OSDMA	Odisha State Disaster Management Authority
PDNA	Post Disaster Needs Assessment
PFC	Power Finance Corporation
PRI	Panchayati Raj Institutions
PSS	Power System Stabilizers
PV	Photo Voltic
REC	Rural Electrification Corporation
SDMA	State Disaster Management Authority
SDMF	State Disaster Mitigation Fund
SDRF	State Disaster Response Force
SDRMF	State Disaster Relief Mitigation Fund
SEC	State Executive Committee
SPV	Special Purpose Vehicle

Abbreviations

SRC	Special Relief Commissioner
T&D	Transmission and Distribution
TPCODL	Tata Power Central Odisha Distribution Limited
TPL	Tonga Power Limited
TPNODL	Tata Power Northern Odisha Distribution Limited
UG Cabling	Under Ground Cabling
UNDP	United Nations Development Programme
UNDRR	United Nations Disaster Risk Reduction
USAID	United States Agency for International Development
USD	United States Dollar
WBG	World Bank Group

Executive Summary

In the realm of power sector, it is increasingly critical to prioritize the upgradation and meticulous maintenance of codes, standards, innovation and technology. This report builds upon the foundation established by the previous report on risk identification and estimation, which served as a pivotal focal point in identifying various priority areas and options related to transmission and distribution (T&D) infrastructure assets in Odisha. This report emerges as a crucial tool for gaining insight into the intricacies concerning standards, codes, regulatory mechanisms, technology and innovation.

The report evaluates existing codes and standards within the T&D sector, recognizing their evolving role amid the changing climate landscape and the emergence of novel risks in Odisha. The findings from this comprehensive analysis go beyond just specific sectoral interests and insights; they are also crucial for interlinked state and national-level agencies. The report aims to strengthen the groundwork necessary for informed decision-making by highlighting the need for improved codes and standards and the exigency for innovation throughout the power sector. Additionally, the report is also positioned to be a vital resource and tool for power practitioners and policymakers alike, offering a detailed understanding of the intricacies that form the functionality of Odisha's power sector.

Component Failure Across T&D Systems

In the coastal state of Odisha, the aging power infrastructure faces a critical threat due to the vulnerability of T&D lines, primarily constructed decades ago in adherence to Rural Electrification Corporation(REC) standards. With cyclones posing an escalating risk, especially to air-insulated switchgear (AIS)-type grid substations, the report begins by underlining the urgency of revisiting these structures. Moreover, field visits have revealed the alarming gap between REC standards and the actual constructions, highlighting vulnerabilities in existing distribution lines made of steel joists and pre-stressed cement (PSC) concrete poles, making them susceptible to failure during cyclones.

In response to these challenges, a comprehensive evaluation was initiated to gauge the resilience of the existing lines. The report navigates through the intricacies of this assessment, ultimately recommending a retrofitting strategy using interposing H-poles. With a minimal weight increase, this solution emerges as a promising measure to enhance the strength of the infrastructure in both transverse and longitudinal directions

T&D lines are integrated systems consisting of towers/poles, conductors, insulators, hardware fittings, foundations, etc. The mechanical supports of T&D lines represent a significant portion of the cost estimates and play an essential role in maintaining a reliable power system. These supports are designed and constructed in various shapes, sizes, configurations and materials per relevant standards.

Most lines and substations in distribution sectors were built in the 1970s and 1980s based on REC construction standards with PSC and joist poles and standard span lengths. However, they are vulnerable to damage at wind speeds exceeding 130-146 km/h. Similarly, most transmission lines are built based on IS 802, considering wind Zone V and may experience structural damage when exposed to wind speeds beyond 170-180 km/h.

Planning and Security for T&D Infrastructure Resilience

Grid substations are mostly AIS type, featuring an indoor control room with outdoor switch yards constructed with lattice structures. Similarly, primary substations (PSS) are also AIS type, with outdoor switch yards made up of joist pole/Lattice structures, with or without a control room. These AIS-type substations are more susceptible to damage in cyclone-prone areas. It is also worth noting that the existing distribution lines are predominately constructed with steel Joist poles and PSC poles, both of which have a rectangular cross-section. Such lines are generally weak in longitudinal directions and fail to withstand the desired wind speed during cyclones.

In Report Strategies for Effective Risk Identification and Estimation, we have identified electrical lines and substations that are exposed to multiple hazards based on their vulnerability and criticality, and risks are identified. This report examines the adequacy of the construction standards and codes for these identified infrastructure in terms of their degree of vulnerability due to multi-hazard risks.

Upon reviewing the construction standards, we also analyzed the gaps in the construction standards against desired wind speed and wind pressure. The gaps between the REC standards and actual constructions were also recorded on a sample basis for the study proposed during the field visits to a few cyclone-prone areas. We further examined damaged structures with probable causes and assessed the wind speed withstanding capacity of the existing T&D lines per IS 5613 and IS 802.

Cost-Benefit Analysis of T&D Infrastructure

The economic ramifications of cyclones further underscore the need for intervention, with damages averaging INR 1,269.5 crores annually and a staggering cumulative loss of INR 25,390 crores over two decades. Recognizing the gravity of the situation, three investment options have been proposed for the DISCOMs.

- **Option 1** involves retrofitting existing lines with H-Pole, E250 grade steel (2x150x75) mm, 36.96 kg for 33kV line and H-Pole, E250 grade steel (2x125x65) mm, 28.82 kg for 11kV line, distribution transformer (DTR) plinth foundation for 100kVA and above, new 33/11kV geo graphic information system (GIS) and retrofitting of existing PSS, at a cost of **INR 22,691 crores.**

- **Option 2** involves the construction of new lines using H-pole E350 grade steel. For the 33kV line (2x150x75) mm, 36.96 kg is required. For 11kV new line H-Pole E350 grade steel (2x125x65) mm, 28.82 kg is needed. Additionally, spun poles for LT new line to replace old lines, DTR plinth foundation for 100 kVA and above, and new 33/11kV GIS, along with the retrofitting of existing PSS. The estimated cost for these activities is **INR 25,628 crores.**

- **Option 3** involves implementing an underground cable system for the distribution network in urban areas, taking priority and criticality into account. This includes using H-Pole for the 33kV new line and 11kV new line, and spun pole in LT new lines for the rural area. Additionally,DT plinth foundation for 100 kVA and above, new 33/11kV GIS and retrofitting of existing PSS. The estimated cost for this project is **INR 26,992 crores.**

Based on the investment proposal, we have evaluated three options categorized as Priority 1, Priority 2 and Priority 3 for each DISCOM. From the above options, Option 3 is recommended for a logical investment of INR 26,992 crores on a priority basis and can be planned in three stages. An immediate focus may be given on Priority 1 with an initial investment of INR 8,419 crores in three DISCOMs.

The report advocates strengthening the lines by adding interposing towers, introducing new 132kV underground cable lines, and converting existing AIS grid substations to GIS.

The estimated investment in this comprehensive overhaul of the T&D system amounts to INR 28,499 crores. It is suggested that a phased implementation approach be adopted to systematically enhance resilience in high-risk areas of high susceptibility, ensuring a strategic and efficient upgrade process

Risk-responsiveness of Codes and Standards

Throughout this narrative, the report also meticulously identifies critical gaps in existing standards and regulations. The need for comprehensive revisions becomes evident, covering aspects such as sag tension calculation, wind mapping, load considerations and right-of-way provisions. This holistic approach aims to address the systemic weaknesses that contribute to the vulnerability of the power infrastructure.

To address this technical issue, tests were conducted to assess the withstand capacity of the existing line by adding a standard H-pole with a slight 6.8 percent increase in weight. The results showed a 119 percent increase in strength in the transverse direction and a 232 percent increase in the longitudinal direction with this small weight change. Further, the strength of existing lines was also examined by retrofitting with interposing H-poles. They were found to be suitable against the wind speed in the region. Based on the findings, H-poles are recommended to be the better option in cyclone-prone areas.

Although retrofitting the existing distribution lines by interposing poles may not achieve 99 percent reliability, it is economical and requires less right-of-way (RoW). On the other hand, constructing new lines with proposed structures (H-Poles in 33kV and 11kV lines and Spun/H-Pole for LT lines) will provide reliability above 99 percent but will not be economical and require more RoW.

Existing transmission lines are constructed as per IS 802:1977 and Wind Zone V as per IS 802:1995. The towers were specifically designed to withstand wind load as per IS 802 specifications for Wind Zone V. Therefore, the proposal is given for strengthening existing lines by interposing towers at available RoW or strengthening existing towers by adding hip bracings. A detailed study is proposed to redesign those lines existing in the coastal zone; however, a tentative investment cost is derived based on our preliminary analysis.

Furthermore, there is a proposal to establish five new 132kV underground cable lines to connect important sources, aiming to meet the demand for critical loads during emergencies. Additionally, plans are to convert eight existing AIS GSSs to GIS in the coastal region. The total investment required for constructing new lines, retrofitting existing lines and converting GSS in the transmission sector is estimated to be INR 2,205 crores.

The total tentative investment in the T&D system stands at INR 28,499 crores, while the probable loss is estimated at INR 25,390 crores. Based on the preliminary study and analysis, investment is feasible, considering both direct and indirect losses to society and the suffering of people in rural areas for extended periods of time.

Although cyclones affect Odisha's entire coast region, cyclonic storms' impact is much more severe in the Ganjam, Puri, Khordha, Jagatsinghpur, Cuttack and Kendrapada districts. Cyclonic storms also impact Gajapati, Bhadrak, Jajpur and Balasore, but the frequency of occurrence and severity are comparatively lower than in the previously mentioned six districts. Some cyclones also impact Nayagada, Dhenkanal Keonjhar and Mayurbhanj, but these are rare occurrences. Other districts do not experience significant impacts from cyclones, and there has been minimal damage to T&D infrastructure in the past.

Hence, it is crucial for infrastructure located in high-risk districts to gradually implement the recommended measures in a phased manner on priority, as classified in this report. The prioritized lines and substations have been categorized into three segments for implementation. However, utilities may plan to implement the above-recommended measures as needed on a case-by-case basis to improve the resiliency of T&D infrastructure.

Technology and Innovation

Amidst these challenges, the report highlights the technological advancements embraced by power utilities in Odisha to minimize the impact of cyclones. The Odisha State Disaster Management Authority (OSDMA) has played a crucial role in introducing early warning systems, satellite phones and other tools. In the transmission sector, represented by Odisha Power Transmission Corporation Limited (OPTCL), innovative designs and configurations are being implemented in cyclone-prone areas. Additionally, the distribution sector, managed by DISCOMs, is adopting resilient poles, underground cabling, GIS Power Substations and smart metering, all of which contribute to a more resilient power distribution system.

The report provides an overview of the different technologies adopted by the power utilities of Odisha to mitigate the impact of cyclones and restore power more effectively than the previous system. The technology choices may be described through two aspects – for power infrastructure (i.e., generation, transmission, distribution) and disaster risk management (i.e., risk assessment, early warning system, monitoring, damage assessment, support in recovery and reconstruction).

The OSDMA serves as the state's nodal agency and is responsible for handling critical situations during calamities. Additionally, power sector stakeholders such as OPTCL, Grid Corporation of Odisha Limited (GRIDCO), Odisha Power Generation Corporation Limited (OPGC), Odisha Hydro Power Corporation Limited (OHPC) and DISCOMs are also responsible for managing their power infrastructure in accordance with their standard operating procedures (SoPs). OSDMA has introduced new technologies such as early warning systems (EWS), satphones and other advanced technologies to ease the operation during pre- and post-cyclone periods.

In conclusion, the report identifies key challenges and provides a cohesive narrative through proposed solutions and recommendations. It underscores the importance of revising standards and regulations, integrating new technologies and adopting a phased implementation approach. This strategic road map aims to develop a cyclone-resilient power infrastructure in Odisha that can withstand cyclones and environmental adversities over the long term. In essence, the report seeks not only to support the resilience of the power infrastructure but also to pave the way for strategic initiatives that will shape the future trajectory of the sector in retrospect.

1 Introduction

1. Introduction

Upon careful consideration, it is evident that conducting a systematic review of the existing standards and codes governing the electrical network and components facing elevated risks from various hazards is the need of the hour. This chapter's evaluation extends to assessing the adequacy of codes and standards in constructing towers and lines concerning associated risks. Recent cyclones in Odisha and Andhra Pradesh further underscore the need for meticulous re-examination of codes as they may lack adequate specifications.

The report emphasizes the importance of generating and analyzing meteorological data to develop codes more rationally, especially considering the significance of wind loads in structural engineering. Additionally, it delves into assessing standards and codes adopted for the existing electrical network/components at high risk due to multi-hazard exposure. The report also examines the adequacy of codes and standards for constructing damaged towers and lines based on the level of risk involved.

On examining the loads on overhead transmission lines, particularly on loads like wind, it becomes clear the critical role of accurate meteorological inputs. The substantial impact of cyclones on the distribution sector, with 80-90 percent of damages occurring in 33kV, 11kV and LT lines, calls for a thorough evaluation of existing codes, standards and regulations. The urgency lies in enhancing infrastructure resilience through code revisions, aligning standards withimplementation, and refining operational and maintenance practices, including vegetation management.

Recognizing the pivotal role of technology and innovation in power infrastructure and disaster risk management, the study aims to enable the power sector to leverage advancements. This involves addressing constraints on accuracy, scale, reach and the capacity to construct, operate and recover damaged infrastructure systems. The report concludes with a comprehensive analysis and recommendations tailored to Odisha's power infrastructure, covering all aspects, from codes and standards to technology and innovation.

Codes currently used in India to determine design wind loads for structures are analyzed and verified for their withstand capacity with available data on extremes. Thus, it is found that IS 802 Part 1/Section 1 and IS 875 (Part 3), along with the National Building Code, specify Ladakh, Mizoram and Tripura in the highest wind zone in the wind map. But as observed, the extreme during the last cyclones is the highest in Odisha, followed by Andhra Pradesh on the east coast.

As the consequence of under specifications can be severe, a careful re-examination of codes must be called for. It is argued that although the available data on extremes may not be complete, they provide a more rational basis for formulating codes. Given the increasing criticality of wind load in structural engineering, a severe effort to generate and analyze the required metrological data seems highly worthwhile. However, procedures followed elsewhere for predicting extreme winds and the nature of gusts must be validated for the country.

The overhead transmission lines are subjected to various loads, including climatic loads (predominant being wind), which depend on the correctness of the meteorological inputs. During cyclonic hazards, electrical components in distribution sectors are notably more vulnerable than transmission systems. It is a fact that 80-90 percent of damages take place in 33kV, 11kV and LT lines during cyclones.

Given the severity of the cyclones in the past and the large-scale damages in the power infrastructure, it is crucial to reevaluate existing codes, standards and regulations. Improving infrastructure resilience can be achieved through changes in codes and standards, bridging the gap between standards and implementation, and improving O&M practices, including vegetation management.

The primary aim of Component II, Task 2 in this study is to fortify the resilience of power infrastructure by developing and updating codes, standards, designs and regulations. This will involve incorporating new technologies tailored to risk exposure and criticality. The task encompasses several critical subtasks aimed at comprehensively addressing the challenges faced by power infrastructure in Odisha. These are as follows:

1 **Existing Designs and Standards:** The first subtask involves identifying and analyzing the existing designs, codes and standards to which OPTCL and DISCOMs in Odisha adhere. This involves collecting relevant data from stakeholders and assessing the steps taken by the Odisha government to implement new designs and standards for resilient power infrastructure.

2 **Gap Analysis and Failure Assessment:** The second subtask focuses on conducting a gap analysis in the designs implemented by DISCOMs and OPTCL. It also involves a failure analysis of power components to determine weaknesses and improvement areas.

3 **Network Design and Reliability:** The third subtask delves into analyzing the design and reliability of the power system network. The aim is to strengthen the infrastructure by identifying critical lines and substations while considering second- and third-order risks. A cost-benefit analysis is conducted, with subsequent review and recommendations for retrofitting and upgrading the system.

4 **Responsive Codes and Standards:** The fourth subtask evaluates the risk responsiveness of existing codes and standards. This involves considering modifications to codes and designs to align with future impacts on the power infrastructure.

5 **Operation and Maintenance Review:** The final subtask involves reviewing and analyzing different stakeholders' operation and maintenance practices. This encompasses restoration efforts and the implementation of new technologies for monitoring and ensuring the safety of critical components. These subtasks collectively contribute to a holistic approach to fortifying the power infrastructure against various risks and challenges.

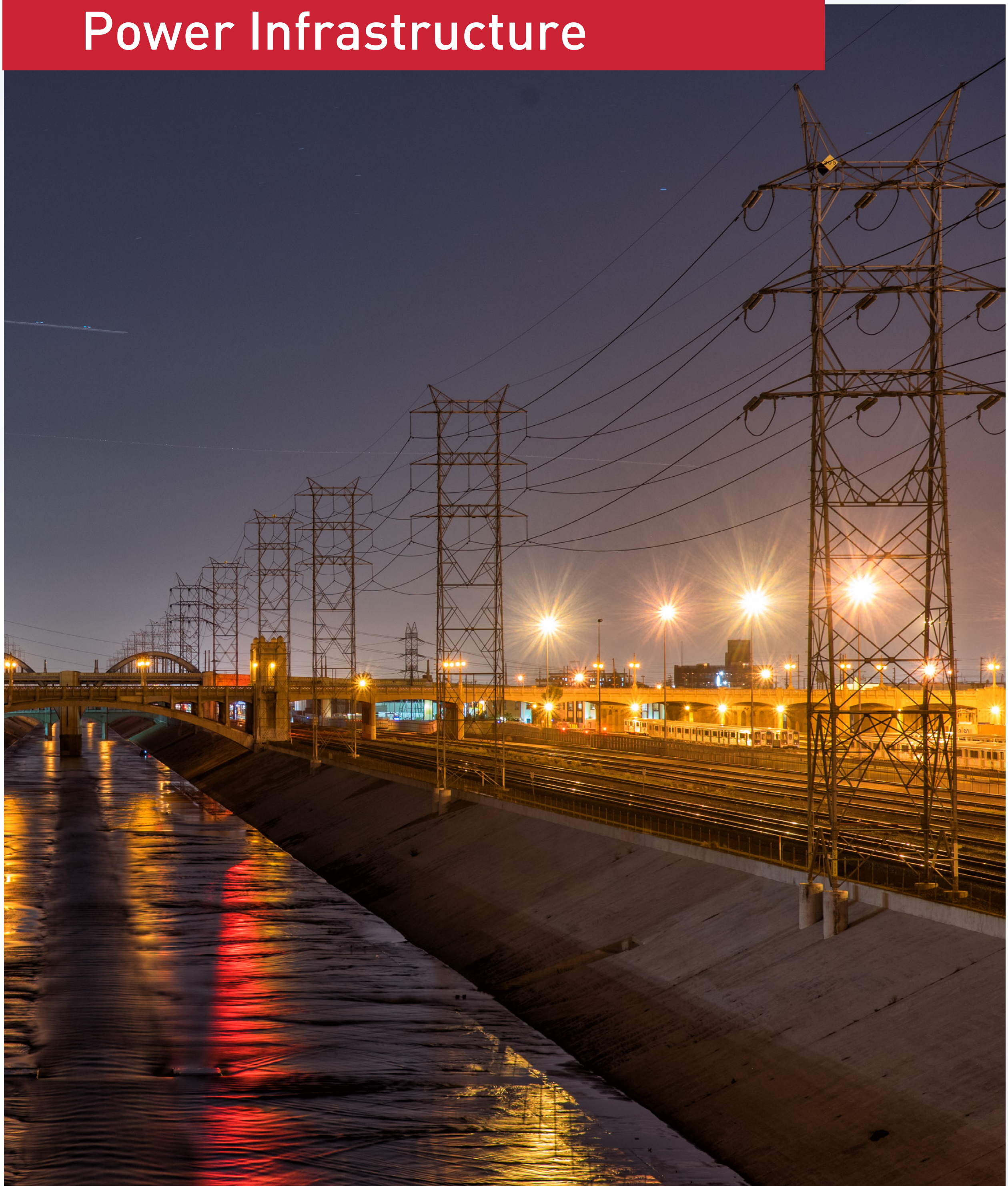
The scope is divided into two fundamental areas: examining codes, standards and the design of established power infrastructure, and exploring the best global practices in technology and innovation. The study will involve the following key components:

Mapping Existing Codes, Standards and Designs: As a part of this study, we have analyzed and compiled data related to codes, standards and designs, specifically focusing on equipment specifications for substations and power lines in the context of cyclones and disasters.

- **Post-Cyclone Fani Impact Assessment in Odisha**
  - Document all modifications made to standards in Odisha following Cyclone Fani.
  - Compile a comprehensive list of interventions carried out in the Puri and Bhubaneswar regions, comparing the present scenario with past conditions to assess the effectiveness of these measures.
- **Review and Recommendations for Power Infrastructure Retrofitting:** Evaluate and propose options to update codes, standards, designs, and operation and maintenance protocols for retrofitting existing power infrastructure. The recommendations should be based on a critical assessment of the infrastructure's vulnerability and a thorough cost-benefit analysis.
- **Documentation of Current Materials and Technologies:** Create detailed documentation of the current materials, technologies and designs employed in power systems for various phases of disaster events—pre-, during- and post-disaster.
- **Analysis of Odisha Government's Initiatives:** Examine the strategies employed by Odisha to establish a resilient power infrastructure, focusing on technological and innovative systems.
- **Recommendations for Technological Innovations:** Enhance power infrastructure and improve disaster risk management based on the technological innovations recommended.
- **Dissemination of Findings:** Share the study's findings with relevant state and national stakeholders to contribute to decision-making in power infrastructure and disaster resilience. This comprehensive approach ensures a thorough examination of existing conditions, a critical assessmentof interventions, and informed recommendations for advancing power infrastructure resilience and disaster risk management.

Component-II, Task-III: Technology and innovation are vital areas and play a significant role in power infrastructure (generation, transmission and distribution) and disaster risk management (risk assessment, EWS, monitoring, damage assessment, support in recovery and reconstruction). This study will enable the power sector to leverage technology to address the constraints on the accuracy, scale, reach and capacity in constructing, operating and recovering (damaged) infrastructure systems. Furthermore, it will also provide the analysis and recommendations for selecting appropriate resilient infrastructure components and procedures for the power infrastructure in Odisha. All the above aspects are thoroughly examined in the report and recommended measures are provided to address their shortcomings.

2 Standards and Regulations in Power Infrastructure



2 Standards and Regulations in Power Infrastructure

2.1 Standards and Codes

Adherence to national and international standards and codes is crucial in ensuring the integrity and reliability of the transmission and distribution (T&D) system. This section provides a comprehensive overview of the standards and codes governing the power infrastructure's materials, design, installation and maintenance. These regulations and reports underscore the commitment to enhancing the resilience and safety of the power infrastructure against diverse challenges. This diverse range of national and international standards and regulations collectively lays the foundation for India's robust, reliable and resilient power infrastructure.

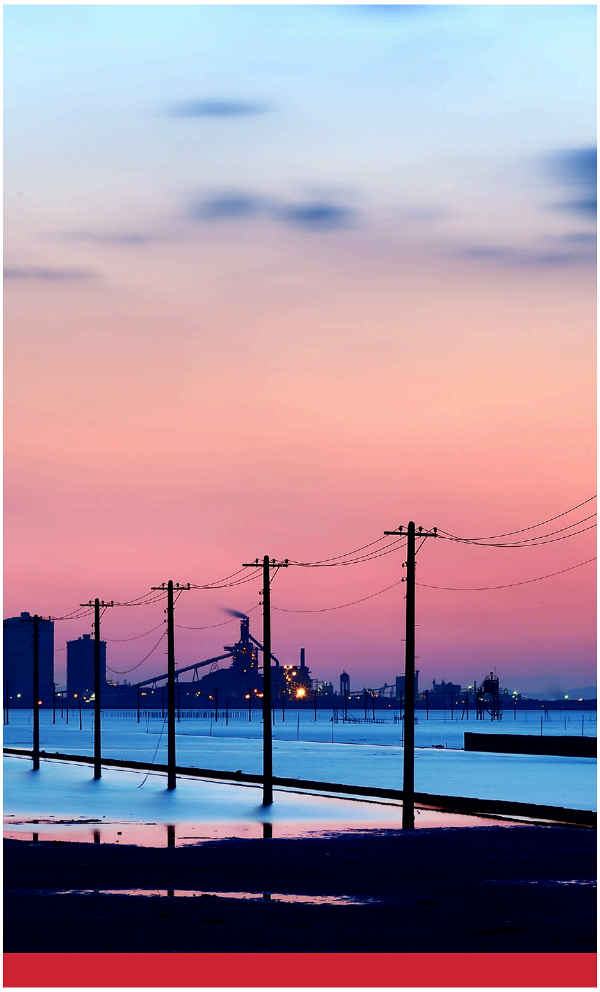
2.1.1 National Standards and Codes

Materials used in the T&D system comply with technical parameters outlined in Indian Standards (IS) by the Bureau of Indian Standards (BIS).

The transmission infrastructure aligns with IS and Central Board of Irrigation and Power (CBIP) manual procedures, while the distribution infrastructure primarily follow Rural Electrification Corporation (REC) specifications, drawings and construction standards, with some modifications by changing the span length and pole size.

Notable national-level codes and standards include those by BIS, REC and the Central Electricity Authority (CEA), such as IS 5613 and IS 802, REC specifications and CEA regulations.

These standards, reaffirmed periodically, govern India's design, installation and maintenance of electrical components. National-level codes and standards for electrical component design, installation and maintenance will be discussed below.



2.1.1.1 CEA Regulations and Reports

The Central Electricity Authority (CEA), as a competent technical authority of the Government of India, formulates regulations in accordance with the Electricity Act of 2010 and carries its provisions.These regulations encompass grid standards for operation and maintenance, safety measures, technical standards for construction and connectivity to the grid. The following relevant regulations are notified and published in the official gazette of the Government of India and available on the CEA website:

26 June 2010
Central Electricity Authority (Grid Standards for Operation & Maintenance of Transmission Lines) Regulations, 2010

20 August 2010
Central Electricity Authority (Technical Standards for Construction of Electric Plants and Electric Lines) Regulations, 2010

24 September 2010
Central Electricity Authority (Measures relating to Safety & Electric Supply) Regulations, 2010

2010
Central Electricity Authority (Technical Standards for connectivity to the grid) (Amendment) Regulations, 2010

14 February 2011
Central Electricity Authority (Safety Requirements for Construction, Operation and Maintenance of Electrical Plant and Electrical Lines) Regulations, 2011

January 2021
Disaster Management plan for the power sector by the Government of India, prepared by CEA

March 2021
CEA Report on cyclone resilient, robust transmission and distribution infrastructure

2.1.1.2 BIS (Bureau of India Standards)

The BIS has published national-level codes and standards in different years and subsequently reaffirmed them. IS 5613 and IS 802 are primarily used for power infrastructure. Table A1.1 lists the relevant standards.

2.1.1.3 REC Specifications and Standards for Distribution System

REC, a Government of India agency, has developed many specifications and standards for distribution lines and substations based on the requirements from time to time. The standards related to overhead distribution lines and substations are tabulated in Table A1.2. REC has developed various construction standards for distribution systems in India, which are detailed in Table A1.3.

2.1.2 International Standards and Codes

Beyond national standards, international benchmarks play a significant role. Different countries publish many standards as per their requirements, and they develop these specifications and guidelines accordingly. The International Electrotechnical Commission (IEC) sets globally recognized standards for the T&D system, which are adopted by many countries. This emphasizes their importance in ensuring uniformity and high-quality benchmarks.

A list of such standards referred to in the T&D system is tabulated in Table A1.4.

2.2 Deviations from National Standards in Odisha

In this section, we will review the improvements, changes and deviations in Odisha state standards compared to national standards.

2.2.1 Advancements and Modifications in Odisha State

In Odisha, the EIC-cum-PCEI, operating under the Department of Energy, Government of Odisha, plays a pivotal role in authorizing changes and deviations from national standards in the design of electrical infrastructure. Aligned with the Electricity Act 2010, these changes are mandated for Odisha's power utilities' adherence.

Upon careful examination and discussions with EIC-cum-PCEI, Odisha, it is evident that the state has embraced innovative practices without significant deviations from Indian standards and codes.

The notable practices include the following:

- Implementing H-type poles and containerized 33kV/11kV primary substation (PSS) under the state-funded 'Odisha Distribution System Strengthening Project (ODSSP)' in cyclone-prone areas.
- Despite being classified in a Wind Zone-5, OPTCL is reconstructing the Pandiabil-Samagara 220kV D/C line and Duburi-Paradeep 400kV D/C line with a tower designed with Wind Zone-6.
- Adopting high-temperature, low-sag (HTLS) conductors and using RCC spun poles in Tata Power Northern Odisha Distribution Limited (TPNODL).
- Tata Power Central Odisha Distribution Limited (TPCODL)'s development of cyclone-resilient poles (Rebar Lacing Poles or RLP) further showcases the proactive measures taken by Odisha's power utilities.

2.2.2 Commitment to Infrastructure Resilience

The above initiatives reflect a commitment to enhancing infrastructure resilience, particularly in cyclone-prone regions. Integrating innovative practices and designs aligns with national standards while balancing adherence to established norms and addressing region-specific challenges posed by climatic conditions. This forward-looking approach taken by Odisha's power utilities demonstrates its commitment to ensuring the robustness and adaptability of its electrical infrastructure.

2.3 Best Practices in Puri and Bhubaneswar Regions

2.3.1 Infrastructure Upgrades, Renovations and Achieved Benefits

Puri City, a renowned ancient pilgrimage site in India, faced acute power supply challenges due to an outdated overhead network and the need for system redundancy. The city experienced frequent and prolonged power outages, lasting 3-4 hours, with interruptions occurring 15 to 20 times daily. These disruptions were attributed to various factors such as saline effects, wind pressure, planned or unplanned shutdowns and even incidents like electrocution of monkeys.

In response to this critical situation, the Government of Odisha made substantial investments, injecting nearly INR 200 crores into the distribution system and INR 450 crores into the transmission system. This financial commitment aimed to enhance power quality and establish a cyclone-resilient network in the region, particularly during the world-famous Nabakalebar Festival 2015. The substantial investment has led to significant improvements, benefiting approximately 40,000 consumers by upgrading the high-voltage (HV) and medium-voltage (MV) distribution systems. The initiative involved renovating and adding crucial power components, including eight PSSs, 400 distribution transformers, 208 ring main units and compact substations.

Furthermore, the project included the installation of a 220/132/33kV grid substation (GSS) at Samagara, a 132/33kV GSS at Samuka and a new 220kV transmission line from Atri to Samagara. Notably, the implementation of network upgrades and an underground (UG) cabling system has proved instrumental in minimizing power outages and ensuring a swift restoration of power supply to Puri City following the impact of Cyclone Fani.

The project addressed the following:

- Strengthening the network for reliable and quality power supply in Puri city.
- Upgrading the distribution system to meet the anticipated demand for a 60 MW load during Nabakale bar Festival.
- Designing the network system with consideration for the impact of the saline effects on the equipment.
- Implementing measures to withstand the system during severe cyclones.
- Reducing T&D loss in the system.
- Introducing supervisory control and data acquisition (SCADA)-distribution management system (DMS) for smart control of Puri City's entire power system to minimize outages and ensure a reliable power system.
- Ensuring round-the-clock power availability in the city for a reliable power system.
- Establishing infrastructure to manage grid efficiency, including a centralized control room or electrical infrastructure.
- Setting up a customer care centre for better service.
- Creating higher power quality indices. Better System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI)

2.3.2 Enhanced Network Connectivity and Stability

Figures A1.1 and A1.2 illustrate the network connectivity in puri, showcasing new lines in a dotted format and highlighting the 33kV connectivity in the ring system. The substations connected in the ring between the two sources ensure a stable and continuous 24x7 power supply in the region.

The T&D system underwent a significant transformation from a radial to a ring system. Previously, Puri town relied on two 33kV feeders from the Puri 132/33kV grid, resulting in poor power supply reliability due to a single source. However, installing the 220/132/33kV GSS at Samagara and 132/33kV at Samuka has dramatically improved power supply reliability.

Figure A1.3 shows all 33/11kV substations are connected in a ring system among multiple sources.

Achieved Benefits of the New Network Construction

The construction of the new network brought about several noteworthy benefits, ensuring a stable power supply to the city:

- The installation of 132kV and 33kV ring networks within Puri town guarantees an uninterrupted and high-quality power supply. Each primary substation now possesses an alternative power source, addressing issues related to coastal winds, saline climatic effects and incidents like monkey electrocution, thanks to the use of UG cabling.
- The upgradation of 11kV lines and the interconnection of 11kV and LT lines have improved power supply quality and reduced outage time.
- The conversion of air-insulated switchgear (AIS) primary substations to indoor gas-insulated substations has notably improved cyclone resilience. These upgraded primary substations can with stand peak demand without overloading transformers.
- The implementation of SCADA automation in substations has enabled online data acquisition and supervisory control, facilitating remote operations for power supply changeovers during exigencies. This has been instrumental in isolating faulty zones in the network and reducing outage time.
- This has ensured quality and reliable power with improved voltage regulation in the subject area.
- The power distribution system prioritizes safety through UG cabling and insulated conductors.
- The power distribution network now presents a neat and aesthetic appearance in this historic tourist destination.
- There has been a remarkable reduction in technical losses within the network.

2.3.3 Smart Grid, Puri

In the transformative Puri Nabakalebar Project, the power system of Puri Town has undergone substantial digitization, resulting in improved power reliability and customer service while also addressing AT&C losses. This initiative, implemented under the Central Electricity Supply Utility (CESU), incorporated supervisory control and data acquisition (SCADA)/DMS/outage management system (OMS) to automate the town's electrical infrastructure. Additionally, a fibre optic/GPRS network has interconnected field equipment, facilitating communication with the central command centre.

In addition to building the communication and control network of these equipment, an Advanced Distribution Management System (ADMS) has also been implemented in this location. This system has revolutionized the electrical distribution system by enabling various innovative and digitized functionalities that DISCOMs have been very keen to adopt, thereby avoiding manual interventions.

The following functionalities of ADMS solutions were implemented as a part of this project:

- SCADA system, information storage and retrieval system.
- Outage management system-customer data management, call management (web call centre), incident management, crew management, prediction analysis.
- Field client for field crew and a web console to monitor the system from a remote location.
- DMS power applications.
- Power flow, state estimator, topology analyzer, tracing.
- Fault location isolation and supply restoration.
- Switching order and work order management.
- Network reconfiguration.
- Interface with geographical information system and customer information system

These functionalities helped OPTCL/DISCOMs significantly improve the overall technical and commercial performance of the distribution network and provide better customer services. This also helped achieve better SAIDI and SAIFI parameters (Power Quality indices).

Smart Grid Stations and Operations

- A smart control centre with a SCADA system and a DMS will help the utility manage field equipment more efficiently while reducing technical losses and customer power outages.
- The OMS will be integrated with the SCADA-DMS solution. The OMS will be used to know the outagesfor the high tension (HT), i.e. 33kV and 11kV, as well as low tension (LT), i.e. 415 V, through the integration of different smart grid systems.
- Planned and unplanned outage management, work order management, automatic vehicle locating (AVL) system, crew management through the AVL system.

- Integration with the following system for smooth flow of day-to-day action
    - Geographic information system (GIS) mapping of Puri Town for 40,000 customers.
    - Creation of manual GIS in ADMS product and provision of integration with GIS System in the future.
    - A web call centre available in the OMS system and future provision to integrate with interactive voice response system (IVRS).
    - Automatic metering infrastructure (AMI) system.
    - Smart infrastructure with remote terminal units (RTUs) and feeder remote terminal units (FRTUs) for MV substations to control and monitor these substations.
    - Metering of distribution transformer.
- Most of the network in Puri town is overhead, which has been automated using the intelligent auto-re closure and sectionalizer with FRTU and fault passage indicator. This equipment sends the signal to the control centre and can be controlled from the control centre.

2.3.4 Cyclone Resilient Power System in Bhubaneswar Command Area

In a proactive move towards enhancing the resilience of its power infrastructure, the Odisha government launched the SCRIPS (State Capital Region Improvement of Power System) scheme for the twin city. The primary aim of this initiative is to build a cyclone-resilient and robust power system network in the capital region, considering the anticipated future load growth in T&D systems based on a system study.

2.3.5 Transmission System Network in Bhubaneswar Area

OPTCL is actively implementing various strategic initiatives to fortify the power system in and around Bhubaneswar City. These efforts align with a comprehensive planning strategy designed to withstand the challenges of cyclones and ensure an uninterrupted power supply.

- Formation of outer ring system in 220kV network.
- Formation of 132kV UG cabling ring network among 132/33kV GSS.
- Installation of new GIS grids in and around Bhubaneswar city.
- Provision of dual source at all GSS.

- Use of 132kV monopoles in transmission lines.
- Replacement of Aluminium Conductor Steel Reinforced (ACSR) conductor by HTLS conductors.

Before the Implementation of the Scheme

Bhubaneswar City used to rely solely on the Chandaka 220kV Grid station for its power supply. This station provided electricity to several substations, including Chandaka 132/33kV GSS, Mancheswar 132/33kV GSS, Ranasinghpur 132/33kV GSS and Kesura 132/33kV GSS. At that time, there was no alternate 220kV source for Bhubaneswar city. All the substations were AIS and connected radially through overhead (OH) lines.

After Implementation of Scheme

The addition of five more 220kV GIS grids, i.e. Chandaka-B, Pratapsasan Balianta, Godisahi and Kantabada, has formed a 220kV outer ring. Additionally, there are five more 132/33kV GIS GSS that are either installed/under construction, along with 132kV UG cabling ring network, which covers Unit-8, Satyanagar,Nayapalli, Mancheswar-B and Badagada. These GIS substations are reliable during hazards and are capable of meeting future load growth in Bhubaneswar City and its peripheral region.

132kV UG Cabling System in Bhubaneswar

OPTCL has constructed or is building many 132kV UG cabling networks to strengthen the transmission system through the SCRIPS and DRPS schemes. The network's SLD is attached in Annexure 5.

Three 132kV circuits have already been charged under the SCRIPS Scheme and successfully operated, as presented in Table A1.5. Seven 132kV UG cable circuits are under construction, with details given in Table A1.6. Additionally, four 132kV UG cable circuits are in the proposal stage under the DRPS scheme. The details are given in Table A1.7.

Conversion of ACSR Conductor to HTLS Conductor

Two overhead lines in Bhubaneswar city were converted from ACSR Panther conductors to HTLS conductors to carry more power during contingency conditions, as given in Table A1.8.

2.3.6 Distribution Network in Bhubaneswar City

In a significant development, 33kV, 11kV and LT OH lines were completely converted from overhead networks to UG networks on four major roads, including connecting streets of Bhubaneswar city under the SCRIPS Scheme. The roads include Cuttack Road, Janpath, Sachvalaya Marg and Bidyut Marg. Furthermore, the construction of seven 33/11kV GIS substations as part of the SCRIPS scheme highlights the commitment to a cyclone-resilient PSS. As shown in Annexure 4 (green highlighted routes), these substations are strategically located along the main roads, with the connecting roads converted to UG cabling systems in important areas of Bhubaneswar city.

UG Cabling Scheme

The UG cabling system has been designed based on N-1 and N-2 contingency criteria, forming a ring network among 33/11kV PSS and 132/33kV GSS to provide multiple sources through 33kV RMUs. Additionally, a ring network was also developed between PSSs through 11kV RMUs and compact secondary substation (CSS) at 11kV level. An LT ring network has also been developed between CSSs through an LT feeder pillar box to provide an uninterrupted power supply to LT consumers. All HT equipment is integrated with FRTUs and connected to the control station using fibre optics. Dual power sources are always available at the consumer end, i.e. in the LT feeder pillar box for LT consumers and in 11kV consumer modules for HT consumers. The UG cables are laid inside RCC trenches with adequate protection from outside forces. In areas with limited access, cables are laid using HDD methods inside HDPE pipes.

The following equipment/circuits have been installed to complete the UG cable system in the specified area.

- **33kV System:** 18 units of 33kV UG cable circuits (117 km) have been laid, forming a ring system among15 units of 33/11kV substations through 10 units of 33kV RMUs in Bhubaneswar city.
- **11kV System:** Similarly, 39 units of 11kV UG cable circuits (228 km) form a ring network among 17 units of 33/11kV substations through 134 units of 11kV RMUs.
- **Power Supply to 11kV Bulk Consumer:** Power supply to bulk consumers is also designed through 236 units of 11kV consumer modules with dual sources.
- **LT Network:** 140 units of compact secondary substations (CSS) with dual 11kV sources have beeninstalled to provide uninterrupted power supply to LT 3-ph/1ph consumers through the UG cabling network. 116 km of LT cables have been laid, forming a ring network among 659 LT feeder pillar boxes to provide power supply to 3500 consumers on four major roads in Bhubaneswar city.

- **SCADA System:** All HT equipment, i.e., 33kV RMU, 11kV RMU, 11kV consumer modules, CSS, are attached with 522 FRTUs connected through UG fibre optics for SCADA operation.

In summary, the SCRIPS scheme represents a comprehensive and forward-thinking approach by the Odisha government and OPTCL to fortify the power system in the state capital region. By implementing strategic initiatives such as the outer ring system, underground cable networks, GIS installations, dual sourcing and advanced conductor technology, the scheme aims to establish a resilient and reliable power infrastructure capable of withstanding the challenges posed by cyclones and ensuring uninterrupted power supply to the twin city.

3 Component Failure Across T&D Systems

3 Component Failure Across T&D Systems

3.1 Primary Survey Review

The team visited vulnerable locations, such as Puri, Berhampur, Paradeep, Balasore and Bhubaneswar. The site visit aimed to check power system components and their implementation standards in the existing networks. The team also collected information data and took photographs of damaged lines and substations. During the site visit, a few discrepancies were observed regarding design and implementation.

Efforts are being made to address these disparities to enhance the power system's resilience. The current imperative involves prioritizing resolving design and implementation disparities, allocating resources efficiently and promptly implementing corrective measures. Sustaining improvements necessitates continued monitoring and regular maintenance.

Case Study 3.1: Bhanjavihar PSS

Figure 3.1: 33/11kV PSS in Bhanjavihar

The Bhanjavihar primary substation (PSS) (see Figure 3.1) is located 7 km from the seashore and gets power supply from two different sources: Narendrapur 220/33kV and Chhatrapur132/33kV grid substation (GSS). It comprises five 11kV feeders, including Karapalli, Golabandha, University and Gopalpur, which fall under the control of the Gopalpur electrical section. The Gopalpur section caters to 12,000 consumers (approximately).

During our site visit to Bhanjavihar 33/11kV substation under Tata Power Southern Odisha Distribution Limited (TPSODL), near Berhampur, on 18 and 19 August 2021, we verified the design of lines and substations. According to the records, the power outage during Cyclone Phailin affected approximately 1 lakh population. As per the data from local authorities, the damaged lines had been restored (line charged) within 45 days from the date of occurrence of Cyclone Phailin, with complete restoration work taking up to three months. According to the data collected from field offices, during Cyclone Phailin, 474 km of 33kV line, 3277 km of 11kV line, 6612 km of LT lines and 2221 distribution transformers (DTRs) were damaged in the TPSODL area. As per the local authority, maintenance work on the power infrastructure, such as substations and lines, is scheduled periodically once every three months. It was observed that most of the substations were 50 years old and the supporting structures were primarily Joist Pole. The team faced difficulties in locating the exact destruction site due to the unavailability of geographic information system (GIS) maps of 33kV, 11kV and LT lines.

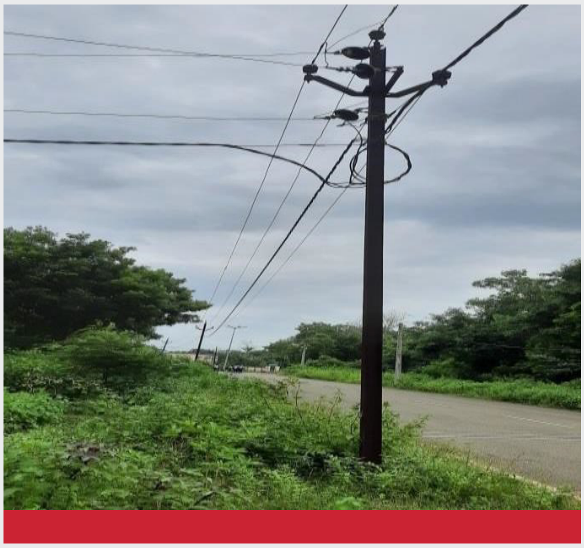
Case Study 3.2: Berhampur PSS

One of the most vital PSSs of Berhampur town, i.e., Old Medical 33/11kV substation, which comes under Berhampur city circle of TPSODL, is situated inside the medical campus and 11 km from the seacoast. It has been serving as one of the oldest PSSs in Berhampur, commissioned during the 1960s and is the mostcritical substation supplying power to MKCG Medical College and Hospital, Berhampur.

Currently, the old medical 33/11kV PSS consists of five power transformers, four 33kV I/C feeders and eight 11kV O/G feeders. It supplies power to critical institutions like medical facilities, water supply, RWSS points, schools, official buildings, etc. During Cyclone Phailin, the substation's 33kV, 11kV and LT lines were severely affected.

Figure 3.2 Existing structures in Berhampur area

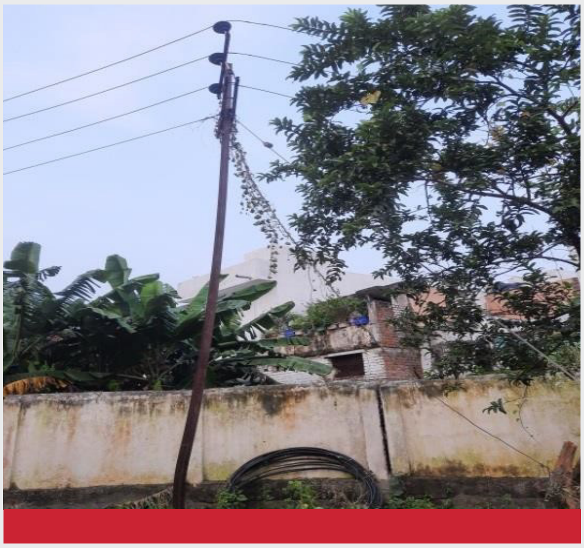
Medical PSS PT with foundation height 0.9 m



Span length greater than 70 m

Figure 3.3: Existing structures at Old Medical PSS

33/11 kv PSS - Old Medical



Pole tilted during Cyclone Phailin

As per the information, the switchyard area gets flooded during heavy rain, with the water level reaching up to 0.7 to 0.8 m in height. Comparatively, the plinth level of the power transformers is only 0.9 m from the NGL, and for the other equipment, it is at a level of 0.2 m to 0. 4 m. Therefore, raising the plinth height of the power transformers and equipment appears necessary.

Case Study 3.3: Paradeep

During a visit to Paradeep (see Figure 3.4), the team observed mainly damages like bending, uprooting and breaking of poles caused by falling trees in the previous cyclone. Four electrical sections, Rahama, Tirtol, Kujanga and Erasama, are consistently affected by cyclones and floods.

Figure 3.4: 33/11kV PSS - Paradeep Gada

The power infrastructure and cable trenches were submerged in flood water up to 1 foot and remained waterlogged for four to five days. It took two days to restore the 11kV feeders, while the LT lines took almost three days to be operational again. The Erasama electrical section under the Tirtol subdivision was the most affected section during the cyclone. In contrast, the Chatua electrical section under the Kujanga subdivision was the most vulnerable section in relation to cyclones. Approximately 150,000 to 200,000 people were affected by the power outage during Cyclone Fani. Local authorities have assured that the department concerned is actively implementing periodic preventive measures and maintenance.

3.2 Observations from Site Visit

The gaps observed during the site visit (refer to Case Studies 3.1 to 3.3) between design and implementation are described as follows:

a) The span length of lines is made without considering the line deviation. Generally, up to 10º deviation, single poles are used. If there is a deviation, either the span length will be reduced or guy support/strut or higher size pole or DP structure sets will be installed. As per REC construction standard (refer to Table A1.9), the following structures with guy support must be adopted. However, they are not observed in some cases.

b) In single-pole and DP structures, the guy supports are as per the stipulations above. Even if the guys are provided, the miscreants cut them. So, these points become very weak and get damaged during a cyclone.

c) In some instances, concrete foundations are established with muffing, although this is not a common practice. DISCOMs address this by installing stay wires and constructing concrete foundations.

d) In case of a deviation, it is necessary to bisect the angle and then install the pole along the bisected line. This is not done during the installation process. Paragraph 3.3 of IS 785:1998 (Reaffirmed in 2014) states that the transverse direction is the direction of the line bisecting the angle between the conductor and the pole.

e) Earthlings are provided in a few lines as per the guidelines. When lightning strikes, it punctures the insulators instead of being discharged to the earth.

f) During joint compression, the appropriate force is not applied to the fittings. There may be over-compression or compression, which will cause the snapping of conductors during the cyclone.

g) Proper tensioning is not applied during the stringing of the lines as stipulated in the IS.

h) IS 4091:1979 stipulates that the depth of the pole's embedment for the foundation should not be less than one-sixth of the total length of the pole above the ground. IS 785:1998 has specified the minimum planting depth for different pole sizes. The embedment depth/ foundation size should be more based on the foundation design for poor soil. However, the same planting depth specified in IS 1678 or shown in REC drawings is maintained for all soils.

i) Only poles are tested at the manufacturer site, but cross arms are not tested for load-with standing capacity.

j) Due to salinity, polymer insulators should be used in coastal areas. However, many of the lines and substations have porcelain insulators.

k) The same design of poles is used in restoration, which leads to repeated failure during cyclones.

3.3 Analysis of Existing Codes and Standards

The following sections would go into the technical analysis of the components in T&D systems to find the reasons behind the failures of the components. The materials used in these systems adhere to the technical parameters outlined in the Indian Standards (IS) published by the Bureau of Indian Standards (BIS). It is noteworthy that while the installation of transmission infrastructure strictly follows IS procedures, the distribution infrastructure generally align with REC specifications, drawings and construction standards. However, some adjustments are made to the span length and pole type.

Failures during cyclones commonly affect supporting structures, conductors and insulators, prompting an examination of standards related to these components. Specifically, IS 802 Part-1/Section-1 and IS 5613 Part-1/Section-1 delineate the design criteria for T&D lines, respectively. This section compares stipulations in these standards and REC standards, focusing on wind speed, wind pressure and methodologies for loading calculations.

The materials used in the T&D system are designed and procured according to the technical parameters stipulated in the IS published by the BIS. While the transmission infrastructure installations follow the procedures in the IS, the distribution infrastructure are mainly laid as per REC specifications/drawings/construction standards with some modifications in span length and pole type. Normally, during cyclones, the failures occur in supporting structures, conductors and insulators. Hence, the standards relating to these components are examined in this context.

The IS 802 Part-1 Section-1 underwent significant changes in 1995, followed by further modifications in 2015. In contrast, there have been no alterations in IS 5613 Part-1/Section-1 since 1985 and REC standards have remained unchanged. This highlights a potential gap in standards evolution, particularly concerning distribution lines, posing a pertinent challenge for ensuring resilience during cyclonic events.

3.3.1 Wind Speed and Wind Pressure in Different Standards

The main issue revolves around the incongruities and potential inadequacies within the Indian standards for electrical conductors under varying weather conditions, particularly in wind pressure and temperature. The specified tension requirements in IS 5613-1985, IS 802-1977 and IS 802-1995/2015 exhibit inconsistencies, with a notable shift in design concepts introduced in the latter standard.

The 1995/2015 standard prescribes tension calculations at minimum temperature and 36 percent of maximum wind pressure, a condition that is seldom applicable, especially for normal span lengths. The concern intensifies in regions like Odisha, where cyclones often occur during late October or early November nights, leading to temperatures as low as 15°C. This results in tensions exceeding those stipulated by IS 802-1995/2015 at 32°C and full wind conditions. The discrepancy raises questions about the adequacy of current standards in addressing real-world scenarios, potentially compromising the reliability and safety of electrical conductors in adverse weather.

It is important to conduct a comprehensive review of the standards, incorporating region-specific climatic considerations. Additionally, establishing more nuanced and adaptable tension criteria that accurately reflect actual operating conditions could enhance the resilience of electrical infrastructure, ensuring a more robust and reliable system in the face of diverse environmental challenges.

In the 1995 and 2015 editions of IS 802, six wind speeds of 33, 39, 44, 47, 50 and 55 m/s are considered. Here, the highest wind speed of 55 m/s is witnessed in Leh, Tripura, Mizoram and a part of Assam, despite the latter three not touching the seacoast. The east coast and Gujarat coast in the west are designated as 50 m/s wind speed zones. See Table 3.1 for wind pressure and wind speed in different IS. 802 (Part 1):1977 and IS 5613 (Part 1/Section 1), identifying the highest wind pressure zone, encompass the east coast from the Bengal coast up to Ramanathpuram.

Table 3.1: Wind Pressure and Wind Speed in Different IS

Description	REC Const. Standard for Poles	IS 5613:1985 for Poles	IS 802:1977 for Towers	IS 802: 1995/ 2015 for Towers
Wind pressure on tower in kgf/m²	50/75/100	100/150/200	130/195/260 up to 30 m height	-
Wind pressure on conductor/ earth wire in kgf/m²			43/45/52	-
Wind speed in m/s	-	-	-	33,39,44,47,50,55

The wind pressure and wind speed values as per different IS are shown in Table 3.2. Based on the formula, wind pressure in N/m2 = 0.6 V^2, where V is the wind speed in m/s.

Table 3.2: Wind Speed Equivalent to Pressure

kgf/m²	m/s	km/h
50	28.59	101
75	35.01	126
100	40.42	146
150	49.51	178
200	57.17	206

The above tables show that the wind speed corresponding to the highest wind pressure of 100 kgf/m² as per REC Standard is equivalent to 146 km/h. On the other hand, according to IS 5613 maps, it is 200 kgf/m² (equivalent to 206 km/h).

IS 5613 (Part 1/Section 1 and Part 2/Section 1) acknowledges considerable assistance from the REC Standard/Construction Manual in preparing the standard.

The majority of the transmission line towers in Odisha Power Transmission Corporation Limited (OPTCL) were constructed per IS 802 Part 1-1977, which used the working load concept with a safety factor in practice. In 1995, this IS was revised to include ultimate load without the safety factor concept. In this revision, a provision was made to include the transverse load on the suspension tower (under broken wire conditions), corresponding to everyday temperature and NIL wind conditions. However, with this stipulation, the suspension towers became weak, leading to many towers in Odisha and other parts of the country failing. Consequently, Odisha ceased the procurement of towers as per the 1995 edition of IS 802, opting to adhere to the design criteria of the previous edition (1977). Approximately 20 to 30 transmission lines were built as per the design of the 1995 edition. During the occurrence of Cyclone Phailin in 2013, the towers designed under both categories of IS failed.

In the 2015 edition of IS 802 (Part 1, Section 1), the tower's drag coefficients (Cdt) have been reduced compared to the 1995 edition. See Table 3.3 for drag coefficients (Cdt).

Table 3.3: Drag Coefficients (Cdt)

S. No	Solidity Ratio	Cdt as per 1995 Edition	Cdt as per 2015 Edition
1	Up to 0.05	3.6	
2	0.1	3.4	1.9
3	0.2	2.9	1.8
4	0.3	2.5	1.7
5	0.4	2.2	1.7
6	0.5	2	1.6
7	0.75	2	1.6
8	1	2	2

In IS 875 (Part III), the force coefficient figures for towers have been increased from the 1987 edition to the 2015 edition, as shown in Table 3.4.

Table 3.4: Force Coefficient

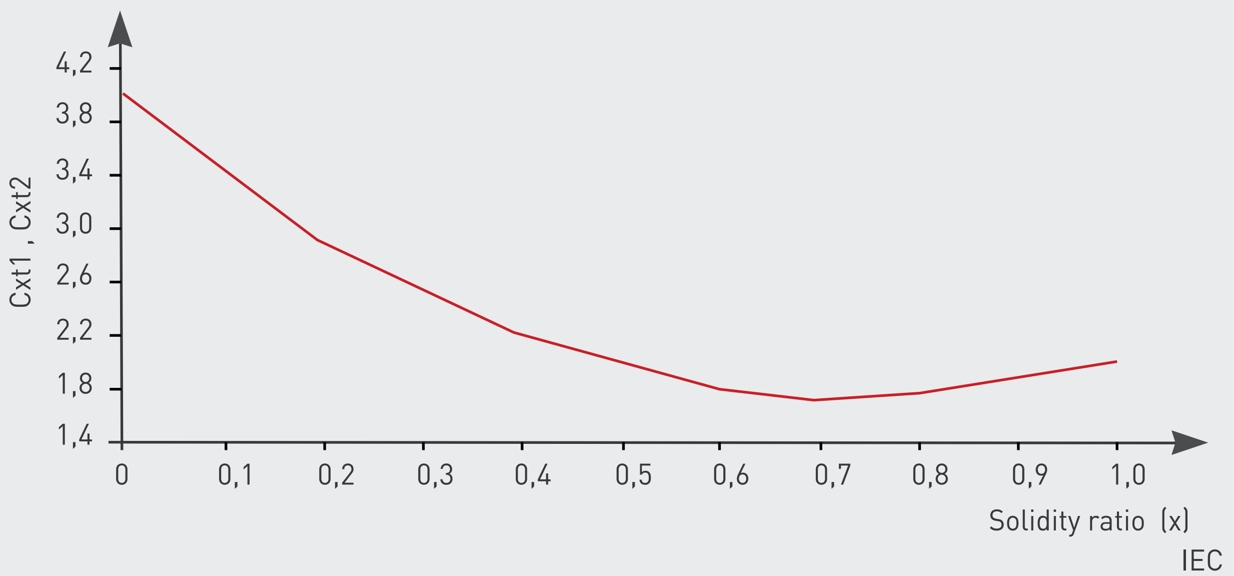
S. No	Solidity	Force Coefficient as per 1987 Edition	Force Coefficient as per 2015 Edition
1	Up to 0.05		
2	0.1	1.9	3.8
3	0.2	1.8	3.3
4	0.3	1.7	2.8
5	0.4	1.7	2.3
6	0.5	1.6	2.1
7	0.75	1.6	2.1
8	1	2	2.1

Observation

a) Building code has increased these coefficients, whereas the transmission line code has decreased.

b) Figure 3.5 of IEC 60826:2017 (furnished below) shows approximately the same figures as furnished in IS 875 (Part III): 2015.

Figure 3.5: Drag coefficient for lattice support



c) The above reductions in drag co-efficient figures in IS 802 (Part 1/Section 1) will severely affect the tower strength, so they need to be maintained in line with IEC 60826:2017.

d) IS 5613- 1985, IS 802-1977 and IS 802-1995/2015 stipulate the two conditions discussed below for calculating sag tension.

First Condition

The first condition is full wind at everyday temperatures. This condition is the same in all the editions of IS 802 (1977, 1995 and 2015). However, in IS 802, the average everyday temperature has been specified as 32ºC, except where the temperature is -5ºC or below. IEC 60826:2017 defines it as the air temperature is equal to the average of daily minimum temperatures peculiar to the site. If statistical data confirm that high winds occur at different temperatures, then the statistical value shall be used. Hence, 32ºC shown in IS 802 needs review as explained below (after the second condition stipulation)

Second Condition

In the second condition, the sag tension calculation varies from IS to IS, as mentioned below:

- IS 5613-1985 specifies tension at minimum temperature and maximum wind pressure.
- IS 802-1977 specifies tension at minimum temperature and two-thirds of maximum wind pressure.
- IS 802-1995/2015 specifies tension at minimum temperature and 36 percent of maximum wind pressure.

The above stipulations cannot be compared since the design concept has been changed in IS 802-1995. However, the second condition, stipulated in IS 802-1995/2015, i.e., minimum temperature and 36 percent maximum wind pressure, is only the ruling condition for very small span lengths. In normal span length, the tension at 32ºC and the full wind are always greater than that at minimum temperature and 36 percent wind pressure.

In scenarios such as when a cyclone strikes Odisha at night or early morning in the last part of October or early November, where the temperature falls to approximately 15°C, the conductor's tension will exceed the stipulated tension at 32°C and full wind as per IS 802-1995/2015.

3.3.2 Transmission Line Failure Analysis

There are various reasons for transmission tower failures due to cyclones. As analyzed, the primary damage to 220kV and 132kV towers happened for the following reasons:

- The failure of a single tower in the line results in the failure of many adjacent towers due to the cascading effect. This was experienced in the Pandiabil-Samagara 220kV line during Cyclone Fani.
- In lattice towers, missing tower members, loosening of nuts and bolts, and improper coping/stubs lead to tower failure. It was seen in Berhampur, where the 220kV towers of the Mendhasal-Narendrapur line failed during Cyclone Phailin.
- Due to the vibration of the tower, the nuts and bolts gradually loosen over time. Inspecting and tightening them at least once every five years is crucial to prevent the structures from weakening. Unfortunately, these essential inspections and maintenance tasks are often neglected, compromising structural integrity.
- Saline deposits on insulators can lead to flashover caused by lightning strikes, resulting in insulator punctures.
- Over time, hardware fittings may become rusted, causing them to lose their original strength.
- In the sea belt, the soil conditions are typically unsuitable for open-cast foundations. So, pile foundations are necessary.

3.3.2.1 Analysis of Transmission Lines Failures – Case of Cyclone Fani

Observed causes of failures of transmission tower in Cyclone Fani are presented below, the data was collected from OPTCL (O&M)

- Severe wind speed and tension on the long-span conductor caused the tower's twisting.
- Severe wind speed and saline effect erosion caused the twisting of the tower.
- Severe wind speed, with a corrosion effect, caused the toppling of the tower.
- Severe wind speed toppled the tower due to the eroding of tower STUB.
- Exposure due to waterlogging and long spans caused the twisting of the tower.
- A topple of 400kV PGCIL tower upon the conductor caused tension and consequence of dragging to tension tower.
- Heavy wind speed and erosion on the leg of the cross arm due to the saline effect caused the bending of the tower peak section.

3.3.3 Analysis of Distribution Line Failure

Failure of Poles

During cyclones or floods, the overhead distribution lines are the most affected assets in the power sector. These assets were constructed in the 1970s and 1980s as per REC standards. The design of distribution lines with pole support is addressed in IS 5613 Part 1/Section-1. IS 5613 Part-1/Section-1 paragraph 14.2 has stipulated to refer to Tables 1 and 2 of IS 1678:1978 (reaffirmed in 2003) for PSC pole dimensions and Appendix A of IS 785:1964 (reaffirmed in 2014) for the selection of PSC poles. While Table 1 specifies only the planting depths of different pole heights, paragraphs 3.2, 3.4, 3.5 and 6.4 of IS 785:1964 address the strength of the pole in the transverse direction. This implies that in a 200 kg 8 m PSC pole, the working force is 200 kg in the transverse direction when applied 600 mm below its top.

In the longitudinal direction, the design working force is 25 percent of the design capacity in the transverse direction. Due to weakness in the longitudinal direction, any falling trees or debris, along with high conductor tension, will damage the pole in the longitudinal direction. Table 3.5 and Table A1.10 presents the design working force/section modulus in transverse and longitudinal directions for different types of poles.

Table 3.5: PSC Poles (Working Force)

S. No	Pole Type and Size	Design Working Force in Transverse Direction	Design Working Force in Longitudinal Direction (25% as per IS 785)
1	PSC 200 kg 8 m	200 kg	50 kg
2	PSC 300 kg 9 m	300 kg	75 kg

Analysis of Conductor Tension

Table A1.11 lists the tensions in conductors with a 70-meter span length, at a speed of 260 km/h and wind pressure of 320 kgf/m², for different temperatures with 25 percent and 15 percent erection tension.

Tension at broken wire Condition

Table 3.6 furnishes the withstand capacity in longitudinal directions of different types of poles and the tension developed in the wire on the broken wire condition at 15 percent erection tension.

Table 3.6: Tension at Broken Wire Condition

Pole Type	Longitudinal Direction Withstand Capacity (in kgf) for Poles		Horizontal Tension (in kgf) for Conductor (in mm²)			
	13 m	11 m	80	100	148	232
150 x150 (34.6 kg) Joist pole	84.7	102.48	75.61	99.20	159.59	278.86
152 x 152 (37.1 kg) Joist pole	123.17	149.02	75.61	99.20	159.59	278.86
WPB 160x160 (30.44 kg)	103.06	124.69	75.61	99.20	159.59	278.86

The above-mentioned poles can work satisfactorily at low wind speeds but are unsuitable for heavy wind speeds. This is because the steel poles are mainly not galvanized. They rust over time and become weak. Moreover, steel poles are meant to have concrete foundations and muffing, but in many cases, this practice is still not widely adopted. As a result, the embedded part of the pole gets eroded in a few years.

3.3.4 Existing Design of Distribution Lines

Odisha DISCOMs generally adopt the following specifications for constructing 33kV, 11kV and LT lines (see Table 3.7).

a. **33kV line:** 150 x 150 mm (34.6 kg/m) RS Joist pole of 13 m and 11 m long (average span length 70x120 m for 80/100/148/232 mm² AAAC (all aluminium alloy conductor).

b. **11kV line:**

   i. RS Joist pole (116 x 100 mm) (23 kg/m) of 9 m and 10 m long (average span length 60-80m for 55/80/100 mm² AAAC).

   ii. PSC Pole (9 m 300 kg) (average span length 60-80 m for 55/80/100 mm² AAAC).

c. **LT Line:** 8 m PSC pole (average span length 40 m for 16 mm², 25 mm², 35 mm² and 50 mm² size of AB cable).

Table 3.7: Existing Design of Distribution Lines

Line Type	Pole Specification	Average Span Length	Suitable Conductor Sizes
33kV	150 x 150 mm RS Joist Pole (34.6 kg/m)	70-120 m	80/100/148/232 mm² AAAC
11kV	RS Joist Pole (116 x 100 mm) (23 kg/m)	60-80 m	55/80/100 mm² AAAC
11kV	PSC Pole – 9 m (300 kg)	60-80 m	55/80/100 mm² AAAC
LT Line	8 m PSC Pole	Avg. span: 40 m	16 mm², 25 mm² 35 mm², 50 mm² AB cable

The analysis reveals that existing span lengths at different voltage levels lack the strength to endure wind speeds of 260 km/h. The wind speed withstanding capacity of current power lines is evaluated based on safety regulations, considering factors such as 1.5 for steel structures, 2.0 for mechanically processed concrete structures and 2.5 for hand-moulded concrete structures as per CEA Safety and Electric Supply Regulations 2010.

The comparison metrics align with IS 5613 and IS 802 for steel poles, while concrete poles are assessed per IS 5613. It is imperative to take urgent measures, such as reducing span lengths and replacing current poles with sturdier alternatives, to enhance the resilience of the power infrastructure.

(i) 33kV line with 150 x 150 mm (34.6 kg/m) Joist poles, 70 m span length with factor of safety: The wind speed withstanding capacity of the line was examined using 150 x 150 mm (34.6 kg/m) Joist poles (13 m and 11 m height) considering 70 m span length with different sizes of conductors as per IS 5613 and IS 802, as shown in Table 3.8.

Table 3.8: Wind Withstanding Capacity in 70 m Span (33kV Line)

Pole Height (in m)	AAAC Conductor (mm^2)	Wind Pressure Withstanding Capacity as per IS 5613 (kgf/m^2)	Wind Speed With standing Capacity (in km/h) as per IS 5613 with formula $P = 0.6 V^2$	Wind Speed Withstanding Capacity (in km/h) as per IS 802 (Reliability Level 1 and Terrain Category 1)
13	80	119	159	148
	100	112	154	144
	148	97	143	135
	232	83	132	125
11	80	155	181	169
	100	144	175	164
	148	125	162	153
	232	105	149	142

(ii) 11kV line with 116 x 100 mm (23 kg/m) Joist poles (10 m and 9 m) and 9m 300 kg PSC Pole , 60 m span length with factor of safety: The wind speed withstanding capacity of the line was examined using 116 x 100 mm (23 kg/m) Joist poles (10 m and 8 m height) and 9 m, 300 kg PSC pole with 60 m span length with different sizes of conductors. This was done as per IS 5613 and IS 802 shown in Table 3.9.

Table 3.9: Wind withstand Capacity in 60 m Span (11kV Line)

Pole Height (in m)	AAAC Conductor (mm^2)	Wind Pressure Withstanding Capacity as per IS 5613 (kgf/m^2)	Wind Speed With standing Capacity (in km/h) as per IS 5613 with formula $P = 0.6 V^2$	Wind Speed Withstanding Capacity (in km/h) as per IS 802 (Reliability Level 1 and Terrain Category 1)
10	55	129	166	156
	80	113	154	147
	100	104	148	141
9	55	145	175	166
	80	127	164	155
	100	116	156	150
9 (PSC)	55	159	183	-
	80	141	173	-
	100	131	166	-

(iii) LT line with 200 kg 8 m, PSC poles considering 40 m and span length with factor of safety: The wind speed withstand capacity of the line is examined using 200 kg 8 m PSC poles considering 40 m span length with different sizes of AB Cable as per IS 5613 and IS 802 shown in Table 3.10.

Table 3.10: Wind Withstand Capacity in 40 m Span (LT Line)

Pole Height (in m)	Type of AB Cable (mm²)	Wind Pressure Withstanding Capacity (as per IS 5613 kgf/m²)	Wind Speed With standing Capacity (in km/h) as per IS 5613 with formula $P = 0.6 V^2$	Wind Speed Withstanding Capacity (in km/h) as per IS 802(Reliability Level 1 and Terrain Category 1)
8	3 x 16 + 25 bare + 1 x 16	230	220	-
	3 x 25 + 25 bare	202	207	-
	+ 1 x 16			
	3 x 35 + 25 bare	172	190	
	+ 1 x 16			
	3 x 50 + 35 bare	144	174	-
	+ 1 x 16			

As per the study, the above span lengths at different voltage levels are not strong enough to withstand a wind speed of 260 km/h. The span lengths need to be reduced, and existing poles need to be replaced with stronger ones.

3.3.5 Conductor Snapping, Damage of Cross Arms and Hardware Fittings

The cross arm supports the tension in the wire, which increases with wind speed. When a tree falls on the line, the cumulative effect of wire tension and tree weight exceeds the capacity of the cross arm, resulting in its failure. In REC standard, only one cross-arm size has been recommended for all wind zones. Table 3.11 represents the working load of cross arms for different sizes.

Table 3.11: Cross-arm Working Load

Voltage	Size and Weight of V-Cross arm	Vertical Load (in kg)	Horizontal Load (in kg)
33kV	(100 x 50 x 6.4 mm) (7.9 kg/m)	400	135
11kV	(75 x 40 x 6 mm) (5.7 kg/m)	300	100

As per the tension developed in horizontal directions (shown in Table 3.11) for higher-size conductors, the cross-arms cannot withstand the tensions in the broken wire conditions. Similarly, the cross-arms cannot withstand the vertical loads if a tree falls on the wire.

REC recommends using an aluminium conductor steel reinforced (ACSR) conductor as it has better tensile strength. AAAC conductors are used in the Odisha Distribution system nowadays due to their better conductivity and less weight. However, these conductors are mechanically weak. Moreover, at the time of installation, if proper compression is not made in the tension clamp, there is every chance of the conductor snapping during the cyclone. Hence, ACSR is to be utilized in coastal areas with proper galvanization of steel wire.

Moreover, with time, oxides form on the conductors, making them brittle. Saline effects also damage the conductors, rendering them unable to withstand the high tension developed during the cyclone. Saline deposits on insulators make them susceptible to flashover, leading to insulator puncture. Hardware fittings tend to rust or deteriorate over time, leading to their loss of original strength. Due to deficiencies in material quality, fabrication, installation, the non-availability of stay sets and the aging effect, the line collapses at much lower speeds.

3.3.6 Analysis of Distribution Transformers Failure

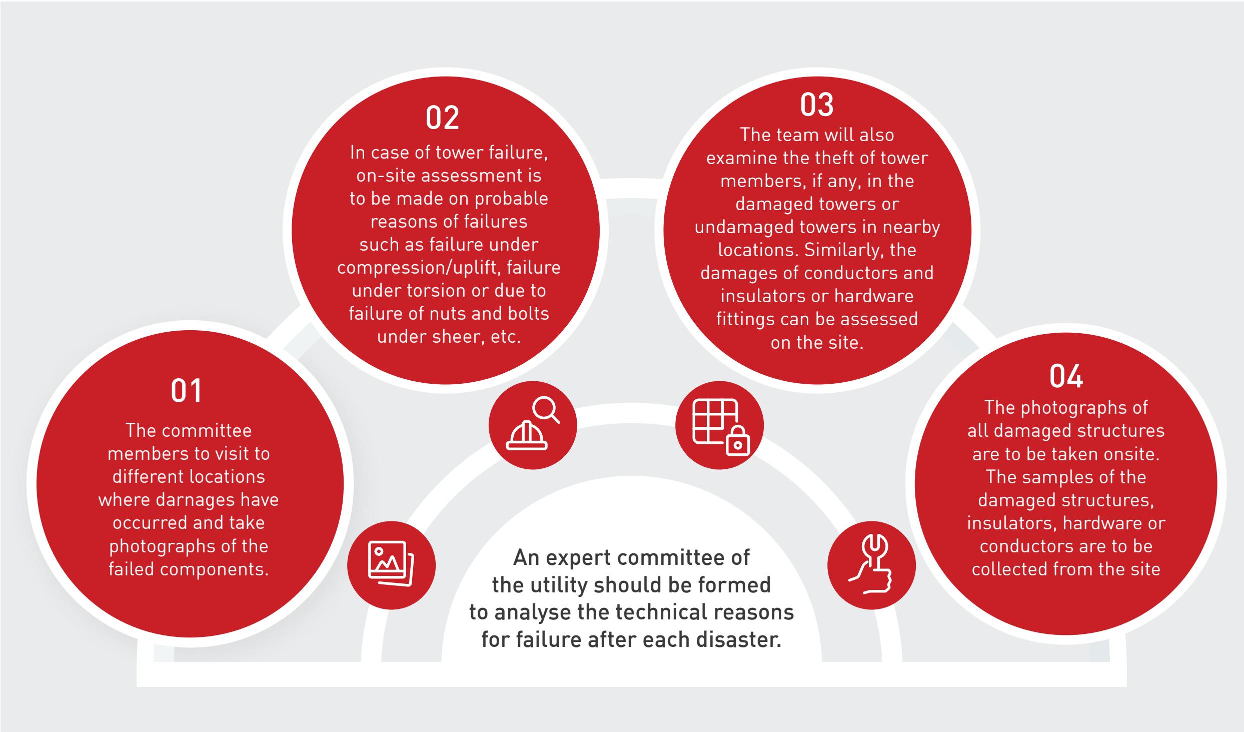
Many poles and DP-mounted DTRs fail during cyclones because they are not designed to withstand the wind loads from DTRs, poles, conductors and their weight.

- In some cases, DISCOMs do not follow REC standards for the installation of DTRs 100kVA and above rating on plinth foundation. Even DTRs of lower ratings mounted on pole structures fail during severe cyclones. In some DP structures, the guy supports are not provided. Even if the guys are provided, they are cut by miscreants, resulting in weakened structures that get damaged during cyclones.
- In some cases, base concreting is not provided to the embedded part of the pole. Photo graphs of some case studies are given in Annexure 6

- Cement poles and joist poles damaged due to long span of conductors.
- Most of the Joist poles weakened from the base due to corrosion and broke even at low wind speeds.
- DP-mounted transformers also fall easily in cyclones as they are not designed to withstand desired wind speeds.

3.3.7 SOP for Technical Evaluation of Component Failure

Figure 3.6: Standard operating procedure for technical evaluation of component failure



The operating procedure for the evaluation of component failure is depicted in Figure 3.6 and consists of four major steps. After the site visits, the expert committee meeting needs to be arranged, and photographs and samples will be examined thoroughly; if required, samples can be tested in the laboratory to find their mechanical strength and aging effect.

The committee report will be circulated to all concerned, including CEA/EIC. If required, one representative from CEA/EIC can be invited to the committee meeting.

3.4 Analysis of Power System Network Planning and Design

Analysis of the power system, network design, system planning criteria (like load limits etc.) and reliability criteria used in Odisha are discussed in this section.

3.4.1 Transmission System

The planning criteria for the state transmission systems are grounded in the security philosophy that has guided its development. This criterion aligns with established transmission planning criteria and guidelines provided by the Central Electricity Authority (CEA). OPTCL, serving as the exclusive transmission company in Odisha, consistently adheres to CEA planning criteria and encompasses reliability considerations.

OPTCL carries out the a 'Five Years Planning study' in accordance with CEA guidelines and obtaining approval from the Hon'ble Odisha Electricity Regulatory Commission (OERC). This comprehensive study delves into the detailed reliability analysis of the existing network, assessing its capacity to accommodate future generations and loads over the next five years, factoring in load growth. Proposed additions of lines and substations at various voltage levels are determined through load flow analysis.

The study also scrutinizes Odisha's load generation balance, considering existing and prospective power generation capacities and loads during peak and off-peak conditions. Additionally, the planning process incorporates contingency analysis to enhance the overall robustness of the state transmission system.

As per CEA Planning Criteria Clause 5

When determining the loading limit for a transmission line, the thermal loading limit is the key factor to consider. The thermal loading limit of a line is determined by design parameters based on ambient temperature, maximum permissible conductor temperature, wind speed, solar radiation, absorption coefficient, emissivity coefficient, etc. In India, all the above factors and, particularly, ambient temperatures in various parts of the country are different and vary considerably during multiple seasons of the year.

However, during the planning phase, the ambient temperature and other factors are assumed to be fixed, thereby permitting margins during operation. Generally, the ambient temperature may be taken as 45°C; however, in areas with lower temperatures, such as hilly regions, adjustments are made accordingly. The design of transmission lines with various types of conductors should be based on conductor temperature limit, right-of-way optimization, losses in the line, cost and reliability considerations, etc.

The return period between the super cyclone in 1999 and FANI in 2019 at Bhubaneswar is 20 years. Hence, the reliability decreased to 97.5 percent as per the formula (1-1/2T) in IS 802. In 1995/2015, it stood at 99 percent as per Table 3.12

Table 3.12: Reliability Criteria as per IS 802:1995/2015

Reliability Level	Line Category	Return Period (in Years)	Yearly Reliability (in Percentage)
1	Up to 400kV line	50	99%
2	Above 400kV	150	99.67%
3	River crossing and special types of towers	500	99.9%

Many GSS located within 60 km from the seacoast receive power supply either in a single circuit or a double circuit in a single tower line. Some GSS are connected from two sources but in a single tower. GSSs that are connected from different sources and different towers are more reliable. Table A1.12 represents the supply arrangement of GSS existing within 60 km of the seacoast.

From the table, it is evident that GSS are at high risk in the case of tower collapse. Some GSS are connected in double circuits, but in single towers, and these are at high risk in cyclone zones because the tower is not designed to withstand wind load as desired.

Projects under construction

1. Construction of 400kV substation at Paradeep and 400kV double circuit line from New Duburi to Paradeep.

2. After the above construction, Paradeep 220kV GSS will have dual sources in two separate 220kV lines, creating redundancy. The new line and GSS are designed with Wind Zone VI in mind.

3. Construction of 220kV D/C line from Pratapsasan 220kV to Cuttack 220kV GSS.

4. After constructing this line, Cuttack 220kV and Bidanasi 220kV GSS will have a dual supply source in two D/C lines. In case of exigency, Cuttack and Bidanasi 220kV GSS will have alternate sources.

5. Construction of Nayapali 132kV GIS and UG cable from Nayapali GSS to Unit-8 GIS.

6. Unit-8 GIS will have an alternate source in case of exigency after the above construction.

7. Construction of Balianta 220kV substation with associated lines.

8. After the above construction, Chandaka A & B 220kV GSS will have an alternate source in case of exigency.

The power supply to 14 GSS locations, including Bhogarai, Jaleswar, Chandipur, Dhamra, Jajpur Town, Konark, Samagara 220kV, Ganjam, Chikiti, Paradeep 220kV, Cuttack 220kV and Bidanasi 220kV, is currently provided through a single line in D/C Tower. In the event of a tower collapse in a cyclone, the power supply to these GSS will be disconnected entirely for an extended period. It is crucial to strengthen these D/C towers to withstand cyclones. Alternatively, planning for possible alternate power supply sources through different lines can be planned, which would work as an alternate feeder in case of tower collapse during the cyclone.

3.4.2 Distribution System

Table 3.13 presents the radial and ring connectivity of the 33/11kV PSS under three DISCOMs, categorized by distances from the seacoast: 0-20 km, 20-60 km and >60 km. It is observed that many PSS are radially fed, and some are in the ring network.

Table 3.13: Radial/Ring-type PSS

DISCOM	0-20 km		20-60 km		>60 km		Total
	Ring	Radial	Ring	Radial	Ring	Radial	
TPCODL	31	47	75	26	-	-	179
TPNODL	25	53	10	41	7	48	184
TPSODL	31	9	28	26	5	8	107

The primary issue revolves around the vulnerability of radial electrical distribution systems, particularly in rural areas, to the impact of cyclones. While urban areas often boast robust ring networks for 33kV and 11kV systems, the conversion of radial systems to ring configurations in rural settings faces challenges, primarily due to significant right-of-way (RoW) issues. Although structures can be fortified to withstand wind speeds of up to 260 km/h, the current distribution landscape in rural regions presents a substantial risk during cyclonic events. The same is the case for the LT line.

Tata Power Central Odisha Distribution Limited (TPCODL) accounts for 41 percent of PSS and is integrated into the radial systems in the Puri, Jagatsinghpur, Kendrapada and Khordha districts. Tata Power Northern Odisha Distribution Limited (TPNODL), comprising 77 percent of the PSS, is part of the radial system under the Balasore, Bhadrak, Jajpur and Mayurbhanj districts. TPSODL, comprising 40 percent of the PSS, is in the radial system under the Ganjam and Gajapati districts. As the radial system is considered more vulnerable to cyclones, PSS, which comes under 0-20 km and 2060 km distance from the seacoast, must be provided with an alternative reliable source.

3.5 Comparison with Global Best Practices

A comparison with global best practices from areas with similar risks is discussed here.

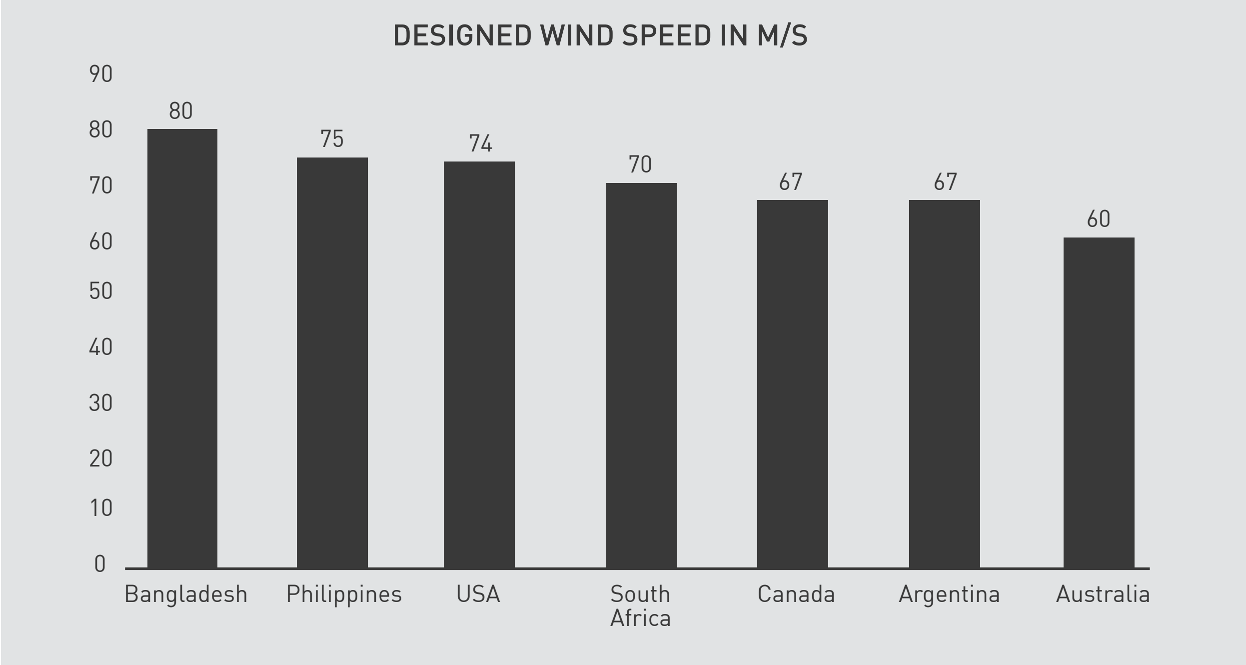
3.5.1 Comparison of International Standards with Respect to Indian Standard

The wind speeds considered in other countries for designing power infrastructure are furnished in Table 3.14 and Figure 3.7.

Table 3.14: Designed Wind Speed in Other Countries

S. No.	Country	Designed Wind Speed (in m/s)
1	USA	71.5-74
2	Argentina	60-67
3	South Africa	70
4	Canada	67
5	Australia	60
6	Bangladesh	77.5-80
7	Philippines	75

Figure 3.7: Designed wind speed (in m/s)



- In India, as per the wind map in IS 802:1995/2015, the maximum wind speed is 55 m/s. For Odisha, it is 50 m/s. These wind speeds are very low compared to those adopted in other countries, as mentioned in Table 3.14.

- As per IEC 60826, the towers are designed for full wind and average everyday minimum temperature. The minimum temperature in Odisha every day is 20°C. At the time of a cyclone at night, at the end of October or November, the temperature goes down to 15°C, but IS 802 stipulates that full wind is considered at 32°C. The full wind at 15°C condition is more stringent than the full wind at 32°C.

- As per Rule 76 of the IE Rules 1956, the state government will specify maximum wind pressure and maximum/minimum temperature. The IE Rule has been superseded by CEA Safety regulation, which says that the maximum wind pressure and maximum/ minimum temperature are as specified in the relevant Indian Standards. Instead of a daily average temperature of 32°C, the average daily minimum temperature may be considered in the IS per IEC.

- The drag coefficients stipulated in IS 802:2015 are much less in IEC 60826:2017. Such low values of drag coefficient weakens the towers.

3.5.2 Disaster Management Policies across the globe

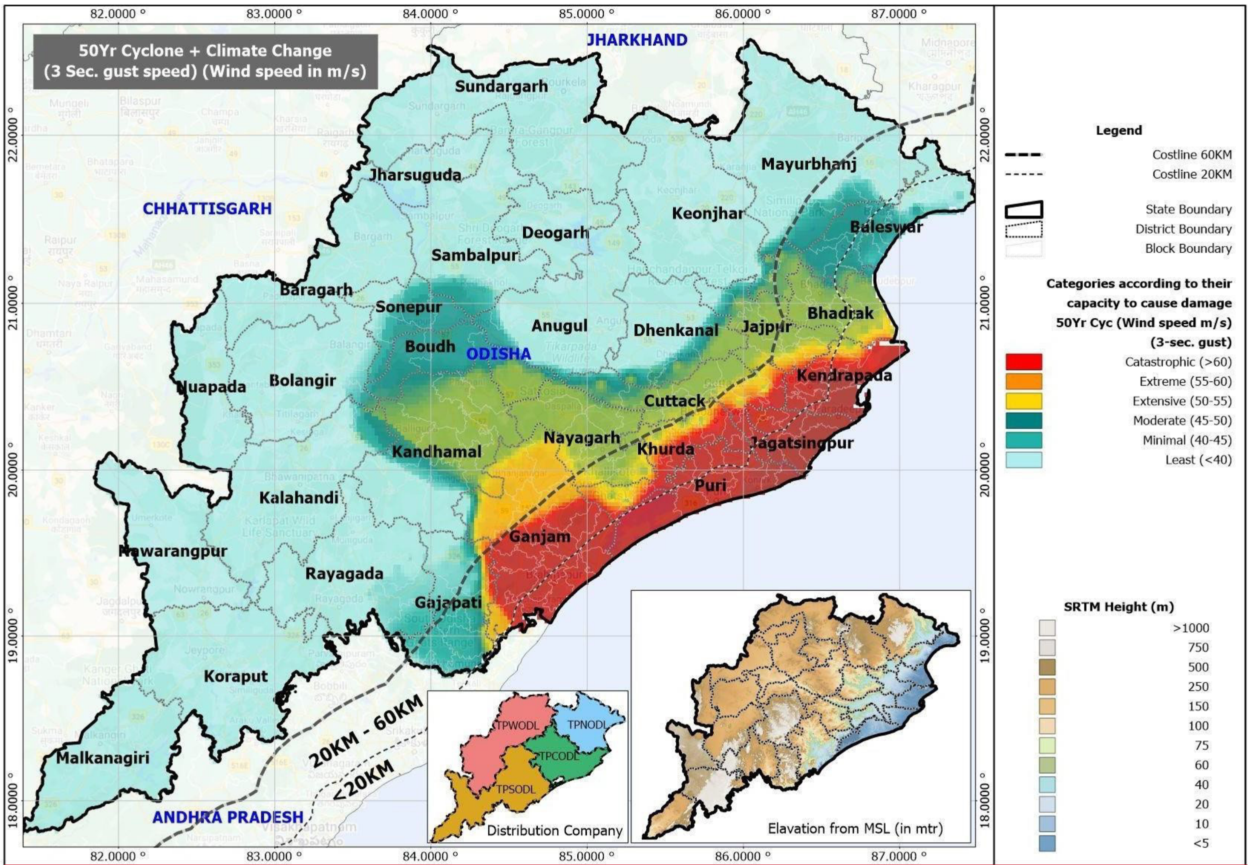
Most countries have their own strategies to mitigate various disasters and have framed policies accordingly. However, all their policies are more likely similar to Indian strategies and policies. The countries have set up their own disaster management plan and policies to tackle various disasters. The disaster management plans adopted by different countries are given in Annexure 7.

3.6 Review of Risk-Informed Standards for 11kV Lines

In assessing the reliability and risk factors associated with power transmission and distribution lines, it becomes imperative to consider the intricate dynamics of wind speed and structural resilience. The reliability of lines at 400kV and below, computed with a 50-year return period, currently stands at 99 percent adhering to the formula 1-1/2T specified in IS 802: 1995/2015 (where T is the return period). Hence, the risk factor for distribution lines is 1 percent.

The existing 11kV systems can withstand wind speeds ranging from 148 km/h to 183 km/h for different conductors at different pole heights. However, a closer examination of the wind map illustrated in Figure 3.8 unveils potential discrepancies, indicating a risk factor surpassing 1 percent. This discrepancy arises as existing structures demonstrate the capability to withstand wind speeds ranging from 130 km/h to 180 km/h. The following discussion delves into the implications of these findings and the need to re-evaluate risk factors in the context of wind speed considerations.

Figure 3.8: Wind zonation map



3.7 Pushing for better standards – Case of Damaged Power Infrastructure

It has been a standard practice for utilities to reconstruct damaged power infrastructure immediately after a cyclone without maintaining the standards and design due to emergency conditions. If they maintain the design standards during reconstruction, it is with the prevailing design, which is not cyclone resilient. Under such a scenario, during restoration work, it is recommended to maintain the following practices:

- The poles designed for 260 km/h will be installed in place of the damaged poles. i.e., the damaged Joist pole and PSC pole are to be replaced by an H-pole in 33kV and 11kV lines and the spun pole or H-pole in LT Lines as per the requirement.
- The span length during erection is to be considered per the design, which can withstand a wind speed of 260 km/h.
- GI poles should be considered instead of MS in coastal areas to avoid damage due to corrosion.
- Porcelain insulators are to be replaced by polymer insulators.
- DTR below 100kVA should be installed in the H-pole and DTR of 100kVA and above should be installed on the RCC plinth.
- Poles with precast foundations can be used for quick restoration of lines.
- LT bare conductors are to be replaced by AB cables during erection.

4 T&D Systems: Planning and Security

4 T&D Systems: Planning and Security

4.1 Retrofitting of Existing Distribution Lines

As the existing steel Joist and PSC poles with rectangular cross sections are weak in longitudinal directions, the poles discussed in the following sections are proposed for retrofitting and new lines. Based on the vulnerability and criticality analysis done in Component-I (Risk Identification and Estimation), retrofitting existing power infrastructure will be done in a phased manner on a priority basis. The retrofitting/new line design for 33kV, 11kV and LT lines is described in the sections below.

4.1.1 Lines with H-Type Poles

In cyclone-prone areas, H-type poles are the better option. The H-type pole is proposed because, with a marginal weight increase of 6.8 percent, the strength in the transverse direction increases by 119 percent and 232 percent in the longitudinal direction strength. Table A1.13 compares the section modulus between the H-pole and Joist pole due to longitudinal and horizontal forces. The section moduli of different types of poles/structures in the transverse and longitudinal directions are also mentioned. The section modulus of H-type poles is tabulated in Table A1.14 while the detailed H-type pole modulus calculation sheet is shown in Table A1.15. The withstand capacity in the longitudinal direction is given in Table A1.16.

Figure 4.1: H-type pole

The H-type pole is one of the most cost-effective structures. It can withstand wind speeds up to 260 km/h and is reliable to use in coastal areas (see Figure 4.1). It can be constructed in any congested area and requires much less space to erect in comparison to NBLS towers or DP structures.

Two galvanized GI channels are rigidly embedded with each other to form a single structure. The robust structure can withstand wind speeds up to 260km/h. The 33kV and 11kV lines (span length 50 m) with H-type poles can be designed with Panther or Dog conductors.

In the region, no structures have been type-tested to withstand wind speeds more than 260 km/h. Wind speed here have been recorded to exceed 198 km/h during cyclones such as Fani, Phailin and Super Cyclone. Considering that 33kV lines are the backbone of the distribution system, it is important to select the supporting structures based on the wind speed.

Interposing with H-Pole of the existing 33kV lines in joist poles with 70 m span: The 33kV line in 150 x 150 mm Joist poles (34.6 kg/m) can be retrofitted with a 70 m span, interposing by 2 x150 x 75 mm H-type poles (36.96 kg/m), E250. Table A1.17 gives the wind speed with a reduced span length of 35 m after interposing.

New line with H-type pole for 33kV lines with 50 m span: The plan involves constructing 33kV new lines with 2 x 150 x 75 mm H Pole (36.96 kg/m), E350 grade with 50 m span length as detailed in Table A1.18. Additionally, the construction of 33kV new DC lines with 2 x 200 x 75 mm H Pole (49.06 kg/m), E350 grade with 50 m span length, as shown in Table A1.19, is also part of the project. It is suggested that a double ckt line with a 232 mm^2 conductor be avoided. The span length will be reduced if there is RoW for two separate lines.

Interposing with H-type pole for existing 11kV lines in Joist poles with 60 m span: The existing 11kV line on the Joist pole (116 x 100 mm, 23 kg/m) with a 60 m span will be retrofitted by interposing with 2 x 125 x 65 mm H Pole (28.82 kg/m), E250 grade. Table A1.20 gives the wind speed with a reduced span length of 30 m length after interposing.

New line with H-type pole for 11kV lines with 50 m span: New 11kV lines with 2 x 125 x 65 mm H-type poles (28.82 kg/m), E350 grade, spanning 50 m, need to be constructed as shown in Table A1.21. Additionally, new 11kV DC lines will be constructed with 2 x 200 x 75 mm H-type poles (49.06 kg/m), E350 grade, also spanning 50 m, as shown in Table A1.22.

LT line with H-Pole-40 m Span: LT line design will incorporate an H-type pole with 2 x 100 x 50 mm dimensions (21.03 kg). The design will be for an 8 m length, considering a 40 m span length for LT lines as shown in Table A1.25.

4.1.2 LT Lines with Spun Pole

The spun pole is manufactured through a high-speed spinning process that ensures a homogeneous mix of concrete, resulting in a high-density concrete pole with a hollow design.

Technical Specification and Standards of Spun Pole

IS 13158 (pre-stressed concrete circular spun poles for overhead power, traction and telecommunication lines) is the code that looks into this aspect.

Figure 4.2: Spun pole installed by APEPDCL in Visakhapatnam City

Figure 4.2 shows a spun pole installed by APEPDCL in Visakhapatnam City. Although spun poles are comparatively heavier and more challenging to transport, they can still be easily transported and erected using the recommended processes for all types of poles, including crane and hydra methods.

The spun poles have the following benefits:

- The poles are tubular in structure, having equal strength in all directions, compared to any rectangular poles, which do not have uniform strength on all sides.
- The centrifugal process involved in spinning gives concrete better and uniform strength, and the outside surface of the pole is stronger and more resistant to cracks.
- Due to the circular form and absence of edges/angles, the magnitude of wind forces is only two-third compared to rectangular poles for the same projected area.
- The poles give a better aesthetic look.
- The hollow portion of the pole can be used as a duct for carrying earth wire(s) or cables.
- High design loads are possible with spun poles.
- They are stronger, uniform and pilferage proof.
- The cost is low and maintenance free.
- Depending on the pole's working load, the number and size of HT steel wires, the grade of concrete and the shell thickness can be modified.
- It can easily be used for single pole-mounted substation/line AB switches as per requirement.
- They are the best economical solution as cyclone-resilient pole.

Design of new LT lines with Spun Poles-30m span: Table A1.23 illustrates the design with a spun pole of 8 m (350 kg), taking into account a span length of 30 m for new LT lines.

Design of new LT lines with Spun Poles-40m span: Table A1.24 showcases the LT line design with spun pole, 8 m (350 kg), considering the 40 m span length shown.

Further comparisons for PSC spun poles are pending and will be based on IS 802, as this standard is intended for steel structures.

4.2 Retrofitting Existing Transmission Lines

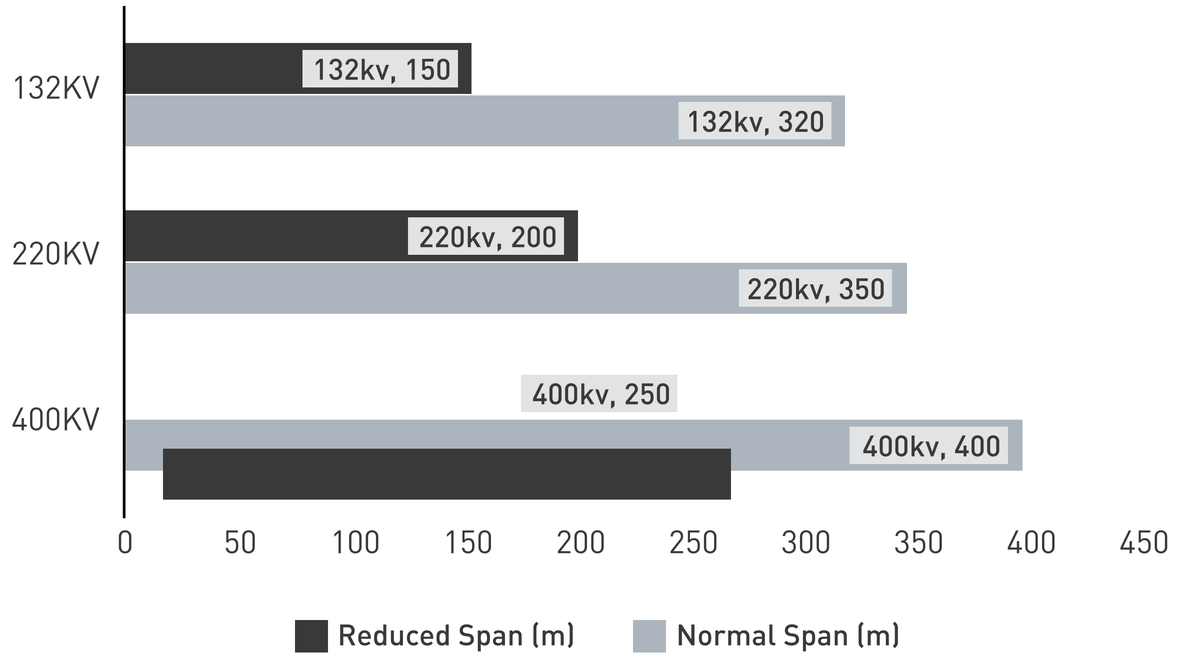
Till recently, Odisha Power Transmission Corporation Limited (OPTCL) had been adopting towers as per IS 802-1977. However, after evaluating these towers for the 220kV line according to the loading criteria in IS 802-1995, it was found that under normal conditions (climatic loads), the suspension towers can withstand gusting speeds of up to 180 km/h (Zone 5) and angle towers (300c and 600c) can withstand the gusting speed of up to 198 km/h (Zone 6). However, when checked for wind speed of 260 km/h, it was found that the existing angle towers are suitable for approximately 130 m span length. In contrast, the suspension towers can handle a load of approximately 100 m span length.

During the presentation at the third meeting of the CEA task force on 19 January 2021, there was a proposal to reduce the span length at different voltage levels (see Tables 4.1 and Figure 4.3). This proposal is in reference to the report of the Task Force on Cyclone Resilient Robust Electricity Transmission and Distribution (T&D) Infrastructure in Coastal Area published in March 21.

Table 4.1: Transmission line span length

Voltage Level	Normal Span (m)	Reduced Span (m)
400kV	400	250
220kV	350	200
132kV	320	150

Figure 4.3: Transmission line span length



Source: Report of Task Force on Cyclone Resilient Robust Electricity Transmission and Distribution (T&D) Infrastructure in Coastal Area published in March 2021. File No.CEA-PS-14-180/1/2020-PSETD Division

In the disaster management plan of the Government of India (prepared by CEA in January 2021), there was a proposal to reduce the span length of 220kV from 350 m to 200 m and for 132kV lines from 320 m to 150 m (see Table 4.2). Most towers in OPTCL are constructed as per HIW (Hirakud Industrial Works) design, with a normal span length of 320 m for 220kV towers and 300 m for 132kV towers. In light of this, it is suggested that interposing towers with a span length of more than 200 m in the case of 220kV and 132kV lines and more than 250 m for 400kV lines be installed. In cases where interposing towers is not possible, the towers can be strengthened by hip bracing.

5 Cost Benefit Analysis

5 Cost Benefit Analysis

Cost-benefit analysis (CBA) is a systematic approach to evaluating the economic feasibility of a project by comparing the expected cost and benefit streams. In the context of the power sector in Odisha, a comprehensive CBA has been conducted for transmission and distribution (T&D) assets. This analysis, encompassing various utilities, includes investment proposals tailored to diverse technical specifications.

The study, detailed in Report 1: Strategies for Effective Risk Identification and Estimation, strategically prioritizes different assets, such as Lines, GIS and AIS, as well as distribution sub-stations. The corresponding cost estimates are formulated for interposing towers and under-ground cable lines based on varying priority levels devised earlier.

The costs of the items have been taken from approved cost data of the Department of Energy, Government of India and CEA cost estimate report, with cost escalation at the rate of 6 percent per annum. For some items for which costs were unavailable, the latest prices have been taken based on market rates.

5.1 Cost Estimate of Distribution System

Based on the vulnerability and criticality analysis, lines and substations were prioritized in Report 1: Strategies for Effective Risk Identification and Estimation as given in Tables A1.26, A1.27 and A1.28. The length of lines was taken from the prioritization table for a cost estimate.

5.1.1 Cost Estimate of 33kV, 11kV and LT Lines Based on Prioritization Categories

Based on the prioritization in the respective tables mentioned in the previous section, the following three options were chosen to prepare the cost estimate for strengthening the power lines. The length of LT lines was calculated using the proportionate ratio of HT to LT in the respective region, as the LT data could not be obtained from the DISCOMs. The LT lines' span length varies from 30 m to 40 m; hence, interposing poles were not proposed here. The plan is to replace the LT lines with spun/H-type poles.

DISCOM-wise investment proposals for different options as per the technical specifications are as follows:

- **Option 1:** The total investment will be INR 22,691 crores.
- **Option 2:** The total investment will be INR 25,628 crores.
- **Option 3:** The total investment will be INR 26,992 crores.

Table 5.1 summarizes the three options, their respective descriptions and total investment amounts.

Table 5.1: Three options and total investment options for lines

Option	Total Investment	Infrastructure Type	Description
Option 1	INR 22,691 crores	Existing Lines	Retrofitting with H-Pole, E250 (2 x 150 x 75) mm, 36.96 kg/m for 33kV line and H-type pole, E250 (2 x 125 x 65) mm, 28.82 kg/m for 11kV line.
Option 2	INR 25,628 crores	New Construction	Construction of new lines with H-type pole E350 (2 x 150 x 75) mm, 36.96 kg/m for 33kV line, H-type pole E350 (2 x 125 x 65) mm, 28.82 kg/m for 11kV new line and spun poles for LT new line in place of old lines.
Option 3	INR 26,992 crores	Underground Cable	Underground cable system for distribution network in urban areas considering priority and criticality. H-Pole for 33kV, 11kV new lines and spun pole in LT new lines for rural area.

Based on the above options, Option 3 is recommended for a logical investment in the following priorities. The total investment can be planned in three stages with a primary focus on Priority 1, involving an investment of INR 8,419 crores (refer to Table 5.2) across all three DISCOMs.

Table 5.2: Option 3 Investment in crores for lines

DISCOM	Priority-1	Priority-2	Priority-3	Total Cost
TPCODL	3,347	4,889	1,678	9,914
TPNODL	2,769	3,793	2,031	8,593
TPSODL	2,303	3,625	2,557	8,486
Grand Total	**8,419**	**12,307**	**6,266**	**26,992**

5.1.2 Cost Estimate of Gas Insulated Substations Based on Priority

The plan is to upgrade the AIS substations existing in important cities within 60-km radius from sea cost to gas insulated substations (see Table 5.3). The cost of each gas insulated substations, and associated works is considered to be a lump sum of INR 15 crore.

Table 5.3: Prioritization of Investment in crores (Gas Insulated Substations)

DISCOM	Proposed New Gas Insulated Substations (in Nos)			Investment (in Crores)			
	P1	P2	P3	P1	P2	P3	Total Cost
TPCODL	0	0	7	0	0	105	105
TPNODL	0	5	0	0	75	0	75
TPSODL	1	9	1	15	135	15	165
TOTAL	1	14	8	15	210	120	345

5.1.3 Cost Estimate of AIS Substation for Retrofitting Based on Priority

In rural and sub-urban areas, it is proposed to retrofit outdoor switch yards of AIS substations with H-type poles (see Table 5.4). The lump sum cost of retrofitting the outdoor switch yard in the H-type pole is estimated at INR 2 crore for each substation.

Table 5.4: Prioritization of Investment in crores (Retrofitting) for PSS

DISCOM	Retrofitting of PSS (in Nos)			Investment (in Crores)			
	P1	P2	P3	P1	P2	P3	Total Cost
TPCODL	18	59	61	36	118	122	276
TPNODL	5	57	40	10	114	80	204
TPSODL	1	34	32	2	68	64	134
TOTAL	24	150	133	48	300	266	614

5.1.4 Cost Estimate of Distribution Substation Based on Priority

DP-mounted distribution transformers with capacities of 100kVA and above are proposed to be shifted to a plinth-mounted arrangement. The cost for constructing the plinth foundation and accessories is considered on a lump sum basis of INR 25,000 per DT. See Table 5.5 for the prioritization of investment in distribution transformers (DTR).

Table 5.5: Prioritization of Investment in crores (DTR)

DISCOM	Proposed Plinth Foundation (in Nos.)			Investment (in Crores)			
	P1	P2	P3	P1	P2	P3	Total Cost
TPCODL	2106	4238	1160	5.27	10.60	2.90	19
TPNODL	910	1091	854	2.27	2.73	2.13	7
TPSODL	761	912	714	1.90	2.28	1.78	6
TOTAL	3777	6242	2727	9	16	7	32

5.1.5 Total Cost in Distribution System

Table 5.6 gives the total retrofitting/new cost of the distribution system, including lines, PSS andDTR.

Table 5.6: Prioritization of Investment in crores (Distribution System)

DISCOM	Priority 1	Priority 2	Priority 3	Total
TPCODL	3,347	4,889	1,678	9,914
TPNODL	2,769	3,793	2,031	8,593
TPSODL	2,303	3,625	2,557	8,486
TOTAL	8,419	12,307	6,266	26,992

5.2 Transmission System

Based on the vulnerability and criticality analysis of 220kV and 132kV lines, they are prioritized in Report 1: Strategies for Effective Risk Identification and Estimation as given in Table 5.7.

Table 5.7: Prioritization of 220kV and 132kV Lines

Voltage Rating	Length in ckM (0-20 km)			Length in ckM (20-60 km)			Length in ckM (>60 km)			Total Length (in km)
	P1	P2	P3	P1	P2	P3	P1	P2	P3	
220kV	92	0	446	0	0	0	0	0	0	538
132kV	123	302	597	0	70	459	0	0	0	1550

5.2.1 Cost Estimate of Transmission Lines with Interposing Towers

The total cost for retrofitting transmission lines with interposing towers exceeding a span of 200 m are given in Table 5.8. The cost of each interposing tower is calculated based on an average weight of tower 8 MT for 132kV lines and 10 MT for 220kV lines in Wind Zone-6. OPTCL has developed different designs of 132kV towers as per CPRI design for Wind Zone 6, which is currently undergoing type testing.

Table 5.8: Prioritization of Investment in crores (Interposing Towers)

Voltage Rating	Prioritization of Lines (in Crores)			Total
	Priority 1	Priority 2	Priority 3	
220kV	21	0	181	202
132kV	41	104	174	319
Grand Total	62	104	355	521

5.2.2 Cost Estimate for Conversion of AIS to Gas Insulated Substations GSS

AIS substations existing in important cities within 60 km of the seacoast are proposed to be converted to gas insulated substations. The cost of each 132kV and 220kV gas insulated substations with associated works is considered to be INR 60 and INR 80 crore, respectively (see Table 5.9).

Table 5.9: Prioritization of Investment in crores (Gas Insulated Substation GSS)

Voltage (inkV)	Proposed new GIS (in Nos.)			Investment (in Crore)			Total Cost
	Priority 1	Priority 2	Priority 3	Priority 1	Priority 2	Priority 3	
220kV	2	1	0	160	80	0	240
132kV	4	1	0	240	60	0	300
Total	6	2	0	400	140	0	540

5.2.3 Proposal for New 132kV UG Cable Lines

Based on the details provided in Table 5.10 of the DRPS Phase-2, the tentative cost estimate for the new 132kV underground cabling is being proposed. The 132kV cable under consideration is a1000 mm^2, single core, copper, XLPE (cross-linked polyethylene) underground cable with RCC trench.

Table 5.10: 132kV UG Cabling Under RPS Phase-2 (Under Proposal)

S. No	From GSS	To GSS	Route Length (in km)	Ckt Length (in km)	Cost (in Crores)
1	Mendhasal 400/220/132kV AIS	Chandaka-B 220/132kV	30	90	129
2	Arugul 132/33kV AIS	Ranasinghpur 132/33kV AIS	30	90	129
3	Narendrapur 220/132/33kV AIS	Berhampur 132/33kV	15	45	64
4	Puri 132/33kV AIS	Samagara 220/132kV GIS	12	36	51
5	Chandaka-B 220/132kV GIS	Brajabiharipur 132/33kV	17	51	73
Grand Total			**104**	**312**	**446**

5.2.4 Total Cost Required for Transmission System

Table 5.11 provides an abstract of the cost estimate required for investment in the transmission system, including lines and GSS.

Table 5.11: Investment in Transmission System

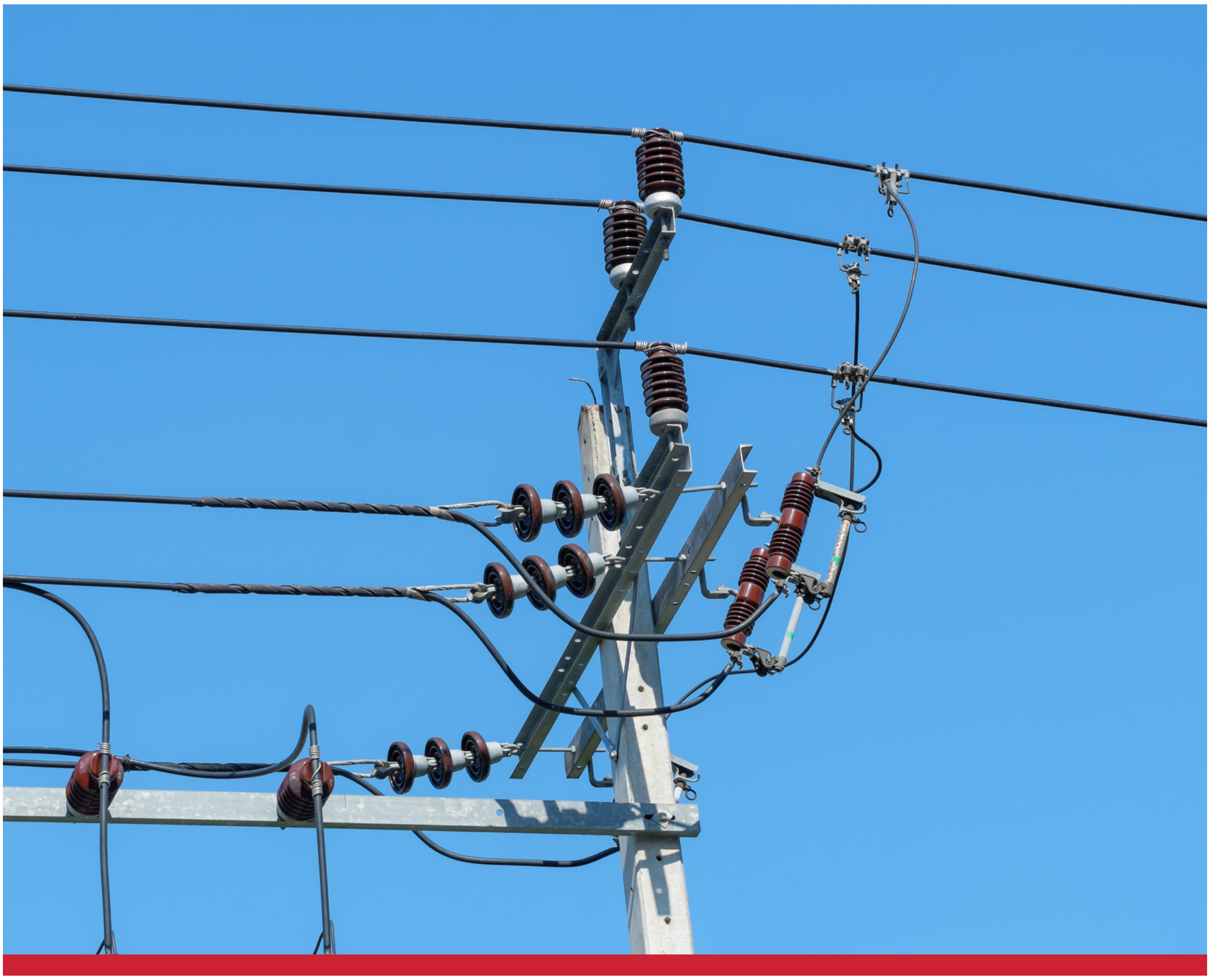
S. No	Proposal	Cost (in Crores)
1	Retrofitting with Interposing Towers	521
2	New 132kV UG Cable Line	446
3	AIS to GIS conversion	540
Grand Total		**1507**

5.3 Total Cost Required for Transmission and Distribution System

Table 5.12 shows the cost of the total investment required for retrofitting/new lines and sub-stations for transmission and distribution (T&D) systems.

Table 5.12: Prioritization of Investment in Crores (Transmission & Distribution)

DISCOM	Priority 1	Priority 2	Priority 3	Total
TPCODL	3,347	4,889	1,678	9,914
TPNODL	2,769	3,793	2,031	8,593
TPSODL	2,303	3,625	2,557	8,486
OPTCL	908	244	355	1,507
Grand Total	9,328	12,550	6,621	28,499



5.4 Cost Benefit Analysis

Data about the revenue loss incurred because of Cyclone Fani is available. The government funded projects that were being executed at the time of Cyclone Fani have been considered. Delays in the capitalization of these projects have contributed to the overall loss, which has been detailed in the assessment of second-order impacts. The second-order losses (revenue loss and project impact) for other cyclones from 2013 to 2021 have been assessed in proportion to the losses caused by Cyclone Fani:

Second-order loss in other cyclones = Second-order loss in Fani/Infrastructure damage cost in Fani) * Infrastructure damage cost in other cyclones. The project impact loss in Cyclone Fani is given in Table 5.13.

Second-Order Loss in Cyclone Fani

Table 5.13: Second-order impact (loss) on ongoing projects

Project Name/Implementing Agency	Original Project Cost (in Crore)
DDUGJY (New) in the distribution sector implemented by OPTCL	1,646
IPDS in distribution sector, implemented by OPTCL	1,078
DDUGJY-XII plans in the distribution sector, implemented by NTPC and PGCIL	3,518
Soubhagya including additional infra in distribution sector, implemented by DISCOMs	1,033
TOTAL project cost' distribution sector	**7,275**
Transmission sector ongoing project cost	**1,000**
Total Project Costs	**8,275**
Due to Cyclone Fani, men and materials from the ongoing projects were diverted for restoration work. Procuring materials against the diverted materials took about three months. Hence, the projects were delayed by about three months. Accordingly, the capitalization of the projects was also delayed by three months. Thus, loss due to a three-month delay in capitalization @ 10% of the capital cost = (7) x 10% x (3/12)	206.875
	INR 207 crores (approximately)

Third-Order Loss in Cyclone Fani

The third-order loss for any cyclone is not available. So, the third-order losses for Cyclone Fani were first calculated as described in Table 5.14.

Table 5.14: Third-Order Loss Due to Cyclone Fani (in 2019-20)

Per capita income in 2019-20 in INR*	104,566	Odisha Economic Survey 2020-21 by Government of Odisha
GSDP in 2019-20 in INR	5,338,220,000,000	Odisha Budget (2020-21) at a Glance of Government of Odisha
Population	45,777,000	Odisha Budget (2020-21) at a Glance by the Government of Odisha
GSDP per capita [two-third] in INR	116,614	
Share of the industry sector to GSDP (36.26%) (in INR)	1,935,638,572,000	Odisha Economic Survey 2020-21 by Government of Odisha
Share of service sector to GSDP (42.47%) (in INR)	2,267,142,034,000	
Share of agriculture and allied sector to GSDP (21.27%) (in INR)	1,135,439,394,000	
Number of days in a year	365	
On average number of days, the industry and service sector were deprived of electricity due to Cyclone Fani	7	
Number of people affected in the cyclone-hit areas	15,993,851	Annual Report on NC 2019-20 by SRC, Government of Odisha
TOTAL GSDP loss due to Cyclone Fani (proportion to number of people affected for the number of days) [2 x 7 x 11/(3 x 9)] (in INR)	35,769,046,368	
GSDP loss in the industrial sector and service sector (third-order loss) due to Cyclone Fani (36.26% + 42.47%) of the above loss [12 x (36.4% +42.7%)] (in INR	28,160,970,206	
Approximately	**2,816 crores**	

*This is for reference only; it is not used in calculation.

Third-Order Loss for Other Cyclones

Based on the information provided in Table 5.15 and Figure 5.1, the third-order loss for other cyclones was calculated proportionately based on the third-order loss in Fani. Detailed losses for various cyclones can be found in the tables below.

Figure 5.1: Third-order loss for other cyclones

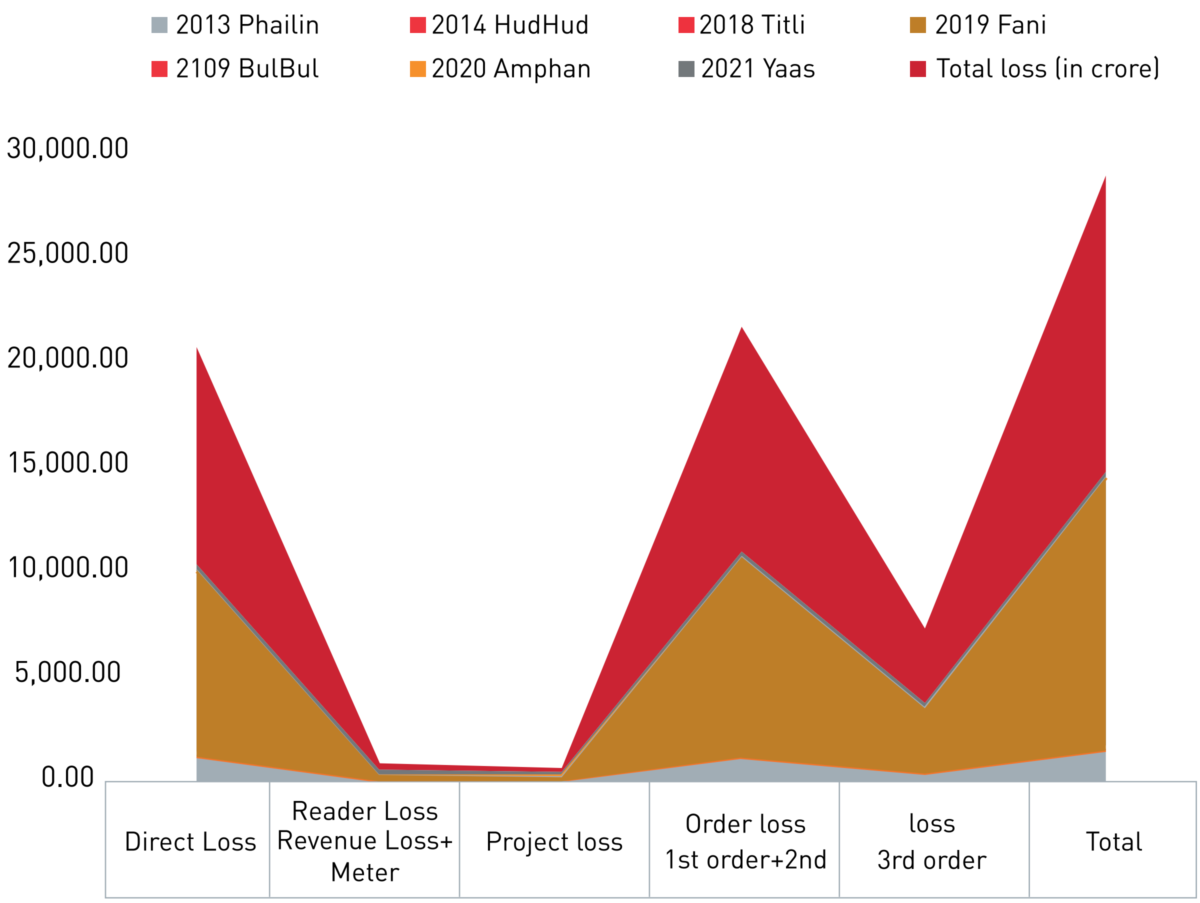


Table 5.15: Third-order Loss for Other Cyclones

Year	Cyclone	Direct Loss	Revenue Loss + Meter Reader Loss	Project Loss	First Order + Second order Loss	Third Order Loss	Total
2013	Phailin	1,048.1	32.6	26.7	1,107.4	362.6	1,470.0
2014	Hudhud	60.0	1.9	1.5	63.4	20.8	84.2
2018	Titli	133.0	4.1	3.4	140.5	46.0	186.6
2019	Fani	8,139.0	253.0	207.0	8599.0	2,816.0	11,415.0
2019	Bulbul	6.3	0.2	0.2	6.6	2.2	8.8
2020	Amphan	76.49	2.4	1.9	80.8	26.5	107.3
2021	Yaas	150.23	4.7	3.8	158.7	52.0	210.7
Total loss (in crore)		**9,613.2**	**298.8**	**244.5**	**10,156.5**	**3,326.0**	**13,482.5**

The total first-order and second-order losses due to seven cyclones in eight years from 2013 to 2021 amount to INR 10,156 crore, averaging INR 1269.5 crore per year. Considering a 20-year infrastructure lifespan, the total loss over 20 years is INR 25,390 crore.

Table 5.12 provides the approximate cost involved in underground cabling and constructing new lines within the existing network based on different design options with respect to resilient power systems. The costs for the distribution network may vary slightly depending on the materials used for overhead networks and underground cable networks.

The total cost of the projects, including the transmission and distribution system, is INR 28,499 crores, whereas the total probable loss in 20 years is INR 25,390 crores

6 Risk Responsiveness of Codes and Standards

6 Risk Responsiveness of Codes and Standards

6.1 General

This chapter delves into the risk responsiveness of current standards and codes governing the power infrastructure in Odisha. It focuses on existing processes, standards and wind zonation maps, underscoring the advantages of revising these codes to align with the evolving climatic conditions in the coastal state. In addition to outlining the benefits, the chapter provides recommendations and a comprehensive list of modifications necessary for enhancing the standards and codes governing transmission and distribution (T&D) assets in Odisha.

6.2 IS 5613 Revision

IS 5613 (Part 1 Section 1) need to be revised in line with IS 802 due to the following two reasons:

- The current wind pressure calculation standards outlined in IS 5613 (Part 1 Section 1) have wind pressure zones with working load and factor of safety concepts. Since IS 802 and IS 875 refer to wind speed, the agencies calculate the wind pressure as per IS 802/IS 875 but do not adopt k1, k2 and k3 factors uniformly.

  Consequently, designs are executed with varying factor of safety criteria in accordance with IS 5613/CEA Safety Regulation, without accounting for gust response factor and drag coefficient factor.

  To address this confusion, a revision of IS 5613 Part 1 Section 1 is necessary. Furthermore, IS lacks specific factor of safety criteria, unlike the CEA Safety Regulation. Variances in K factors and wind pressure calculations by different agencies have been observed, as per Table A1.29, particularly in the calculation of wind load on a cylindrical body with an effective area of two-thirds of the projected area exposed to wind pressure as per IE Rule 76(2b).

  This IE rule has been superseded by the CEA Safety and Electric Supply Regulation 2010. The CEA Regulation 58 (8)(II) specifies that for cylindrical bodies, the effective area considered for wind pressure should be the full projected area exposed to the wind pressure, unlike the two-thirds of the diameter of the conductor for wind load calculation mentioned in IS 5613. Notably, IS 802, in its 1995 and 2015 editions, has indicated the consideration of the full projected area of the conductor for wind load calculation.

- Power Grid Corporation of India (PGCIL) has proposed to BIS the addition of a tower erection as a new part of IS 802. Consequently, the revisions of IS 5613 Part 2 and Part 3 should be synchronized with the revisions of IS 802 (CEA Task Force Report, March 2021).

6.3 Wind Map Revision

The wind map for Odisha needs to include an assessment of the impact of climate change. It has been determined that most of Odisha's coastal region face wind speed >216 km/h (Suggested to use 260 km/h wind speed in the calculation). This justification is based on the following explanation:

(a) Previously, India was divided into three wind pressure zones, with the Odisha coast falling under the category with the highest wind speed zones. The map is shown in Figure 6.1.

(b) In 1987, the building code IS 875 underwent modifications to replace the previous three wind pressure zones with six wind speed zones. At that time, the available data was limited. Subsequently, in 1995, the transmission line IS 802 was modified with these six wind speed zones. The gusting wind speeds (3-second average) for each zone are as follows: Zone I – 33 m/s, Zone II – 39 m/s, Zone III – 44 m/s, Zone IV – 47 m/s, Zone V – 50 m/s (applicable to parts of Assam, the coastal belt of West Bengal, Odisha, Andhra Pradesh, a portion of the Tamil Nadu coast and the coast of Gujrat) and Zone VI – 55 m/s (relevant to Ladakh, Tripura, Mizoram and a portion of Assam). The map is shown in Figure 6.2.

Figure 6.1: Old wind zonation map

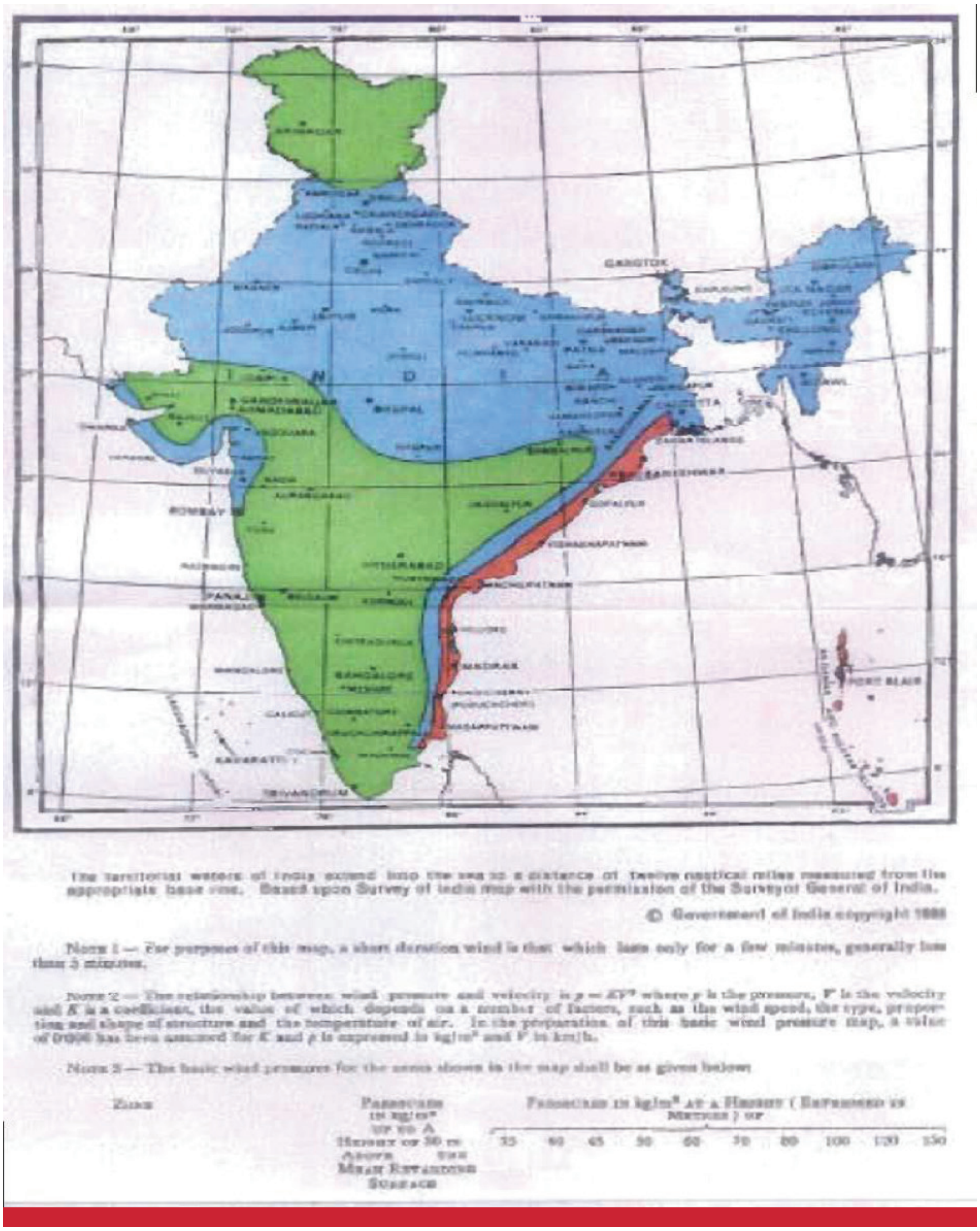
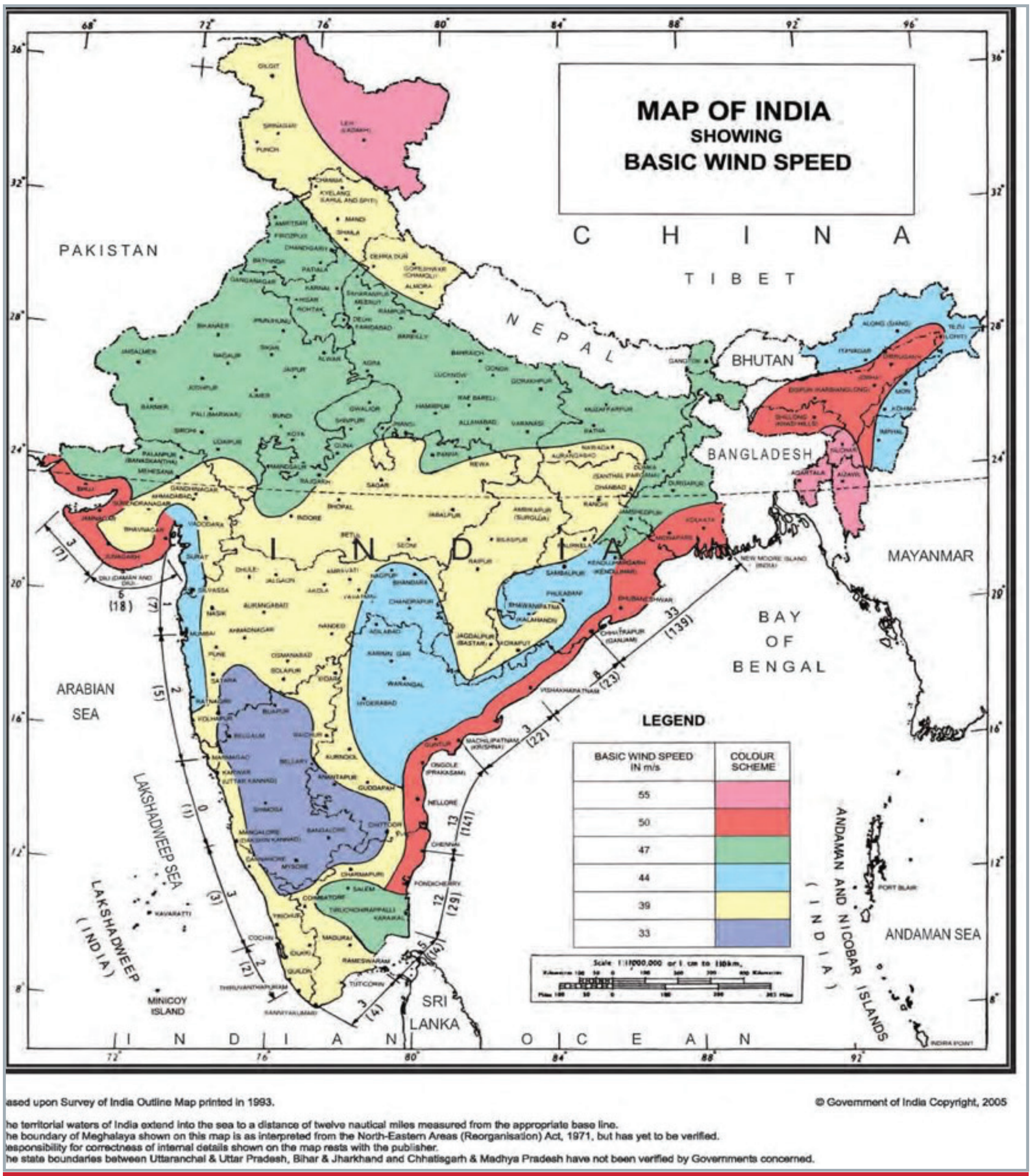


Figure 6.2: Basic wind speed map

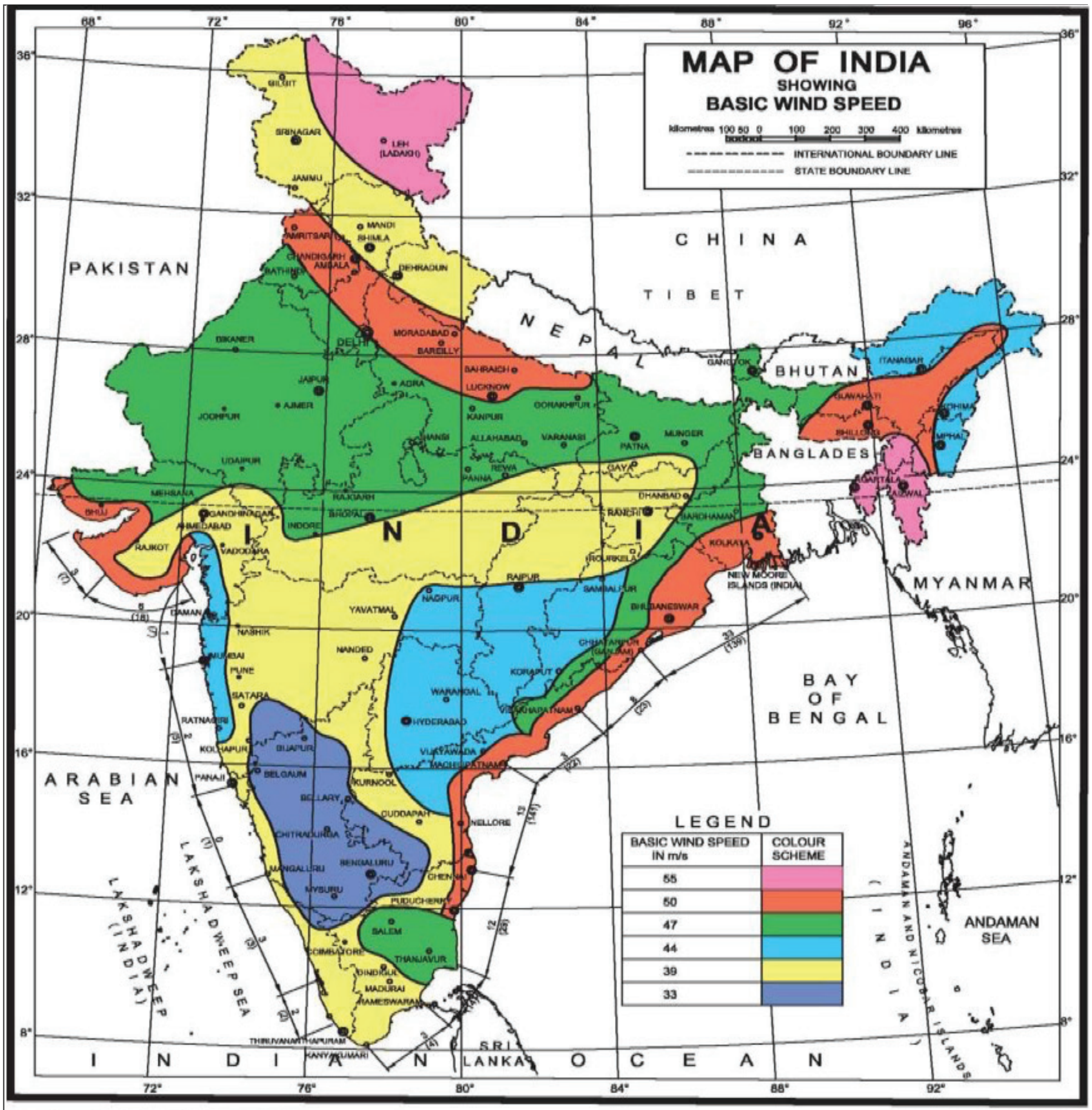


The wind map, formulated between 1964 and 1983, relied on data from 43 dines pressure tube (DPT) anemograph stations. However, it lacked comprehensive meteorological data from nearby locations. Additionally, the mapping did not incorporate data from the Indian Meteorological Department (IMD) website after 1990, omitting localized high-intensity wind conditions during cyclones. Annexure 2 illustrates cyclone intensities with maximum sustained wind speeds from 1990 to 2020.

Notably, four cyclones [i.e., Super Cyclone (1999), Phailin (2013), Hudhud (2014) and Fani (2019)] made landfall in Odisha, each with wind speeds exceeding 100 nautical miles/h (Annexure 3).

Hence, the Odisha coast should be classified under Wind Zone VI instead of Wind Zone V as specified in IS 802 Part1 Section 1. The map issued by the National Building Code in 2016 has undergone some modifications. The map is shown in Figure 6.3.

Figure 6.3: Basic wind speed (in m/s) (based on 50-years return period)



Based upon Survey of India Political map printed in 2002.

The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate baseline.

The interstate boundaries between Arunachal Pradesh, Assam and Meghalaya shown on this map are as interpreted from the North-Eastern Areas (Reorganization) Act, 1971, but have yet to be verified.

The state boundaries between Uttarakhand & Uttar Pradesh, Bihar & Jharkhand, and Chhattisgarh & Madhya Pradesh have not been verified by the Governments concerned.

The administrative headquarters of Chandigarh, Haryana and Punjab are at Chandigarh.

The external boundaries and coastlines of India agree with the Record/Master Copy certified by Survey of India.

The responsibility for the correctness of internal details rests with the publisher.

NOTES

1 The occurrence of a tornado is possible in virtually any part of India. They are particularly more severe in the northern parts of India. The recorded number of these tornados is too small to assign any frequency. The devastation caused by a tornado is due to exceptionally high winds about its periphery, and the sudden reduction in atmospheric pressure at its centre, resulting in an explosive outward pressure on the elements of the structure. The regional basic wind speeds do not include any specific allowance for tornados. It is not the usual practice to allow for the effect of tornados unless special requirements are called for as in the case of important structures such as, nuclear power reactors and satellite communication towers.

2 The total number of cyclonic storms that have struck different sections of east and west coasts are included in Fig. 1, based on available records for the period from 1877 to 1982. The figures above the lines (between the stations) indicate the total number of severe cyclonic storms with or without a core of hurricane winds (speeds above 87 km/h) and the figures in the brackets below the lines indicate the total number of cyclonic storms. Their effect on land is already reflected in the basic wind speeds specified in Fig. 1. These have been included only as additional information.

In the map (as shown in Figure 6.3), the following three changes have been made.

(a) One belt between Amritsar, Chandigarh, Delhi, Moradabad, Bareilly and Lucknow changed from Zone IV to Zone V.

(b) The area covering Raipur, Jagadalpur and Koraput changed from Zone II to Zone III.

(c) A narrow strip between Rourkela in Odisha and Vishakhapatnam in Andhra Pradesh changed from Zone III to Zone IV. However, the areas of concern in coastal Andhra and coastal Odisha have remained the same in the wind map.

(d) IS 15498 2004 (Guidelines for improving the cyclonic resistance of low-rise houses and other buildings/structures) states that due to the greater degree of turbulence associated with cyclonic storms, an enhanced factor of 1.3 (to take care of high-speed wind and turbulence nature of wind during cyclone) should be considered for structures.

(e) This factor was addressed in Building IS 875 as k4 for the East Coast and Gujarat, covering for a belt of 60 km, when the IS was revised in 2015.

(f) In the same year (2015), IS 802 was revised for transmission lines. However, this revision did not take certain factors into account. While building codes include a factor of safety, IS 802 for transmission lines does not. Hence, the k4 factor must be considered in the transmission system.

(g) Incidentally, the Disaster Management Plan for the power sector of the Government of India (January 2021) prepared by the Central Electricity Authority in Chapter 6.1.2.1 Cyclone and in the CEA task force report in March 2021 suggests considering the K4 factor for transmission lines in cyclone-prone areas.

(h) If the east coast (Odisha and Andhra) is changed to Zone VI, with the k4 factor, the wind speed comes to 198 x 1.3 = 257.4 km/h, approximately 260 km/h.

7 Operation and Maintenance

7 Operation and Maintenance

7.1 OPTCL's O&M Standard Operating Procedures

Odisha Power Transmission Corporation Limited (OPTCL) adheres to a comprehensive maintenance manual outlining periodic checks crucial for optimal performance. The specified items for condition monitoring encompass tower foundation, ground earth connection, tower vibration indicating potential loose bracings, signs of rust on tower members and vigilance against theft of tower components. Furthermore, additional checks involve verifying vibration damper displacement, inspecting for trees or bushes near conductors, and employing thermo-vision cameras for line surveys.

OPTCL's maintenance manual specifies the periodic checks for the following items:

- Condition monitoring of the tower foundation
- Ground earth connection for corrosion, loose bolts and nuts, or any other damage
- Tower vibration, which may indicate loose bracings
- Sign of tower member rusting
- Theft of tower members
- Checking of vibration damper for displacement or missing
- Trees or bushes growing under the tower, around the climbing leg, or near the conductors and damaged or chipped insulators
- Surveying the line with a thermo-vision camera, etc.

The main danger to towers during a cyclone is the theft of tower components and the loosening of nuts, bolts and rusted tower components. OPTCL should vigorously monitor these with the help of appropriate third-party auditing systems.

7.2 SOP for the O&M Followed by DISCOMs

The DISCOMs generally follow the REC manual for the operation and maintenance of 33kV, 11kV, medium- and low-voltage lines. This manual was originally issued in 1975 after receiving approval from the Technical Committee on Standardizations during its meeting in January 1975. Subsequently, the manual has been updated until the end of 1983.

The power route, design, materials selection while constructing sub-transmission and distribution lines greatly reduce the impact of external factors during abnormal conditions such as storms and falling of trees. However, the reliability of power supply through overhead lines ultimately hinges on the efficiency of line maintenance.

The maintenance work pertaining to the overhead lines generally consists of the following:

- Systematic pre-planned routine inspection followed by necessary preventive maintenance.

- Periodical inspection in the winter season followed by necessary maintenance to prevent possible outages.

- Special inspection conducted after each and every interruption of line to pinpoint the nature of the defect, followed by necessary repairs.

- The important components of 33kV, 11kV and LT distribution lines are as follows:

  a. Supports and cross-arms

  b. Insulator and fittings

  c. Conductors and accessories

  d. Guys and accessories

  e. Gang-operated switches and fuse units

7.2.1 Maintenance Practice

Proper maintenance of electrical systems is essential for minimizing or preventing unwarranted breakdowns of lines and improving reliability. The overhead lines should be inspected periodically for maintenance purposes to detect any fault that may lead to the breakdown of the electric supply. Necessary repairs should be scheduled promptly thereafter.

During patrols, it is crucial to take note of tilted poles, deformed or tilted cross arms, settling or bulging soil around pole foundations, yielding foundations, cracks or breaks in the poles (PCC/RCC) above the ground level, missing/loose nuts, rust and cracks in the cross arms, and missing stays/struts, among other potential issues.

7.2.2 Restoration Practice

The restoration phase starts after conducting a thorough assessment of the damage following the disruptive incident. This evaluation may reveal the necessity for refurbishment or potential replacement of components. In urban areas, this process typically spans two days, while in rural areas, it extends to a week due to the absence of a supervisory control and data acquisition (SCADA) system and smart meters with a communication link to the data centre. Throughout the restoration phase, any damage to the premises and facilities is repaired. The technical team finalizes the restoration plan, and the operation team executes the plans on-site.As an immediate response to the disaster, ensuring clear access roads to critical areas, locations, and installations becomes the top first priority, utilizing available resources to facilitate expedient restoration.

After conducting a thorough investigation, the lines and equipment with minimal impact will be gradually charged from 33kV to LT lines. Once the restoration and repair work at the affected locations are completed, the remaining lines/substations will be checked and charged according to the standard procedure. In the event of a disaster, priority is given to restoring the 33kV power supply up to 33/11kV substations. Subsequently, priority is given to the restoration of 11kV feeders, distribution transformers (DTRs), and then LT lines. Priority is also given to resuming power supply to critical facilities such as hospitals, water supply, communication and broadcasting station/network, district headquarters, sub-division headquarters, railways and relief camps.

7.2.3 Vegetation Management followed by DISCOMs

For vegetation management, DISCOMs follow no clear guidelines, but tree trimming is carried out based on specific site requirements. Existing poles and conductors suffer damage from trees falling during cyclones, leading to damage to poles and conductors. It is essential for DISCOMs to establish and enforce a vegetation management policy or guideline to address this issue effectively.

7.2.4 Review of Existing Processes to Monitor Right-of-Way

In IS 5613, the right-of-way (RoW) has been defined for lines with voltage ratings of 33kV and above. However, it does not specify for 11kV and LT lines. The RoW guidelines in the Ministry of Environment and Forest are specified in Table 7.1 and the minimum clearance between trees and lines is described in Table 7.2.

Table 7.1: RoW Guidelines of Environment and Forest

Line Voltage	RoW in meter
11kV	7
33kV	15
132kV	27
220kV	35
400kV	46

Table 7.2: Minimum Clearance between Tree and Lines

Line Voltage	RoW in meter
11kV	2.6
33kV	2.8
132kV	4.0
220kV	4.6
400kV	5.5

The Section 68(5) and section 68(6) of Indian Electricity Act 2003 stipulates the following:

Section 68(5) states that if any tree standing or lying near an overhead line or where any structure or other object that has been placed or has fallen near an overhead line subsequent to the placing of such line, interrupts or interferes with, or is likely to interrupt or interfere with, the conveyance or transmission of electricity or the accessibility of any works, an executive magistrate or authority specified by the appropriate government may, on the application of the licensee, cause the tree, structure, or object to be removed or otherwise dealt with as he/she thinks fit.

Section 68(6) states that when disposing of an application under sub-section (5), an executive magistrate or authority specified under that sub-section shall, in the case of any tree in existence before the placing of the overhead line, award to the person interested in the tree such compensation as he/she thinks reasonable, and such person may recover the same from the licensee.

Explanation: For the purposes of this section, the expression 'tree' shall be deemed to include any shrub, hedge, jungle growth, or other plant.

Even though the provision and act forbid the growth of any tree near the electric lines, it is observed that in some instances, the landowners are not allowed to cut the trees beyond a specific limit. During cyclones, the trees sway heavily or fall on the lines, thereby causing damage to the power infrastructure. Hence, it is proposed to establish a district-level committee consisting of the following members:

- Representative of district magistrate
- Representative of the district forest department
- Representative of the horticulture department
- Representative of electricity utility (and will be the convenor of the committee)

The utility will keep the committee informed about any obstructions encountered during tree cutting near the line. The committee members may visit the sites and give suitable suggestions to the district magistrate to ensure timely tree clearance.

Although the RoW for 11kV and LT lines have not been specified in IS, a RoW of 7 m can be taken for both 11kV and LT lines.

7.3 Development/Improvement of Standards for O&M of T&D Infrastructure of 11kV Lines and Distribution Lines

- All the angle points should be provided with stay/guys/strut as per the REC construction standard.
- All steel poles are to be provided with a concrete foundation with muffing.
- Earthings are to be provided at the poles.
- Damaged insulators are to be replaced.
- All loose points are to be checked by a thermo-vision camera.
- All tilted poles/cross arms are to be straightened.
- In long spans, interposing poles are to be installed.

7.4 Monitoring of Power Lines and O&M

Review of technology options for regular monitoring of power lines and O&M standards for critical components.

a) GIS Mapping of Power Infrastructure

The power distribution company is responsible for ensuring that electricity is available to end consumers and managing HT and LT electrical networks and related consumers across a wide geographical area. While most DISCOMs currently use traditional physical area maps for operations and system management, OPTCL has implemented GIS mapping for all the transmission lines.

The main objective of GIS is to efficiently manage the power distribution system and improve metering, billing, revenue collection, network performance optimization, reducing AT&C losses, regular O&M, outage management, asset management, future planning, customer satisfaction, etc. GIS maps are now crucial for identifying the most critical infrastructure that come under the most vulnerable areas severely impacted by cyclonic hazards, providing a clear understanding of the network's current status and future planning. GIS allows for the visualization of various types of data on a single map, making it easier for individuals to see, analyze and understand patterns and relationships. Once we have this knowledge, we can take appropriate action. This geographi cally based management approach is revolutionizing organizational operations. The scope of GIS in the power distribution network will involve mapping of all assets (33kV/11kV, LT), including HT and LT network entities up to poles and major landmarks, collecting consumer attributes through door-to-door surveys, indexing them with network assets and overlaying the digitized electrical network and consumers on the base map with area features and attributes for GIS application. Additionally, it will involve integrating the GIS system with other IT applications.

b) Implementation of UAV and Sensor for Inspection

Climate change and cyclonic events present both long-term and short-term risks to energy infrastructure, resulting in power outages, heightened maintenance needs and increased capital costs. Unmanned aerial vehicle (UAV) solutions have gained widespread acceptance among power utilities and renewable energy companies in many countries such as Australia, Canada, the People's Republic of China (PRC), Spain, the United Kingdom and the United States. This is particularly evident among power companies managing extensive networks of transmission lines, spanning tens of thousands of kilometres. For instance, the national grid in England and Wales has successfully utilized six drones for the past two years to facilitate the inspection of its 7,200 miles of overhead lines (Vaughan 2018). Similarly, Duke Energy of North Carolina in the US has integrated drones to inspect infrared equipment, survey storm damage and inspect tall structures (Wells 2018). Equipped with sensors and cameras, UAV are capable of capturing visual, infrared or ultraviolet images and detecting various faults or defects.

The visible light camera serves as the primary equipment for capturing high-resolution images of power line components and parts. It is crucial for inspecting and identifying defects such as broken wires, loose bolts, damaged insulators, pollution flashover and damper deformation. On the other hand, the infrared camera functions as a thermal detector, identifying overheated fittings or parts resulting from mechanical or mounting defects, and can also be used for monitoring wildfires along line corridors. Lastly, the ultraviolet camera is used to examine discharges by detecting corona or arc on conductors, insulators or fittings.

During hazards like cyclones and floods, accessing affected areas can be challenging, causing delays in rescue operations. UAVs can play a crucial role in conducting post-disaster inspections and impact surveys. By providing valuable imagery, the maintenance team can promptly assess the damage, prioritize operations and allocate resources effectively. Furthermore, the data collected can assist grid in quickly restoring power, thereby expediting the entire repair and recovery. In addition, drones equipped with specialized tools like lasers, flame guns, or electric wires can be used to remove hazardous items such as kites, balloons and plastic bags from facilities. Moreover, in the event of a power failure, UAVs can significantly expedite the fault location process, which is often time-consuming and imprecise when done manually within the power system.

7.5 Upgradation of Power Infrastructure

7.5.1 Replacement of OH Lines by UG Cabling System

Figure 7.1 Prefabricated half-cut hume pipes

All 33kV and 11kV feeders in urban areas are proposed to be converted to an underground cabling system. To ensure a reliable power supply during emergencies, most of the trunk lines will be connected between two sources for alternate power supply during exigencies. The preferred choice is the use of 33kV and 11kV, 400 mm2, single core, XLPE, corrugated aluminium sheath UG cable. Depending on the availability of RoW, the cable trench can be directly buried or installed through prefabricated half-cut hume pipes (as shown in Figure 7.1)

7.5.2 Installation of 11kV Ring Main Units

Figure 7.2: Ring main units

This is one of the most critical cyclone-resilient equipment that ensures uninterrupted power supply to the region even during exigencies [see Figure 7.2 for ring main units (RMU)]. The 11kV RMUs consist of SF6 circuit breakers and load break switches (LBS), allowing them to operate with at least two incoming sources in the circuit. The number of LBS and circuit breakers are designed as per the distribution schemes with the provision of SCADA automation in the future.

7.5.3 Conversion/Renovation of LT Lines

Based on the site conditions, we need to replace LT lines with AB cables. All overhead conductors in the LT lines should be converted to LT AB cable and any defective poles must be replaced. Intermittent poles may be required to reduce the span length. Some existing poles require proper erection with cooping, while damaged poles/eroded poles need to be replaced. Additionally, LT lines within cities should be converted to an underground cabling system with feeder pillar box arrangements.

Based on the site conditions, LT lines in rural areas should be replaced with either H-type Joist poles or only Joist poles. If necessary, the LT lines if required may be bifurcated to ensure a balanced load.

7.5.4 Cyclone-Resilient Distribution Substations

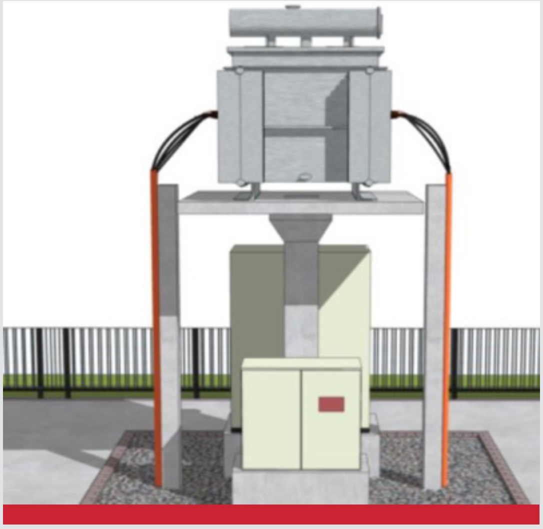
a) Plinth-Mounted Prefabricated Foundation

Figure 7.3: Plinth-mounted prefabricated foundation

DP-mounted distribution substations are more vulnerable to cyclones. These substations such as 25kVA, 63kVA, 100kVA, 250kVA and 500kVA require renovations with prefabricated foundations and other necessary accessories. The existing DTs are either pole-mounted or plinth-mounted and some of these substations need to be renovated or converted to prefabricated foundations with additional accessories. The renovation involves DPs, replacement of AB switches, installation of LA, HG fuse, LT panel, LT cable, earthings and more. See Figure 7.3 for an example of a plinth-mounted prefabricated foundation.

b) Outdoor Plinth-Mounted DT and Compact Secondary Substation

Figure 7.4: Single LBS with DT



This option is highly recommended for installing UG cabling networks in cyclone-prone areas. It requires less space and is more cost-effective compared to compact secondary substation (CSS). Each DT will have one LBS (refer to Figure 7.4) and can be operated through common controlled switches. Many DTs can be remotely group controlled for maintenance or during exigencies. It is a cost-effective solution that also requires minimal space. The design makes it easy to retrofit the existing DP-mounted substations.

Figure 7.5: Compact secondary substation

Compact-type secondary substations (see Figure 7.5) are recommended for use in urban areas in the UG cabling system. These substations are equipped with a transformer, 11kV RMU and LT distribution panel with feeder remote terminal units (FRTUs) for SCADA automation. They are designed to be fully protected from outer forces and can be operated both remotely and locally. It is possible to design CSS in various sizes, especially for higher capacity substations, which is the preferred approach. For smaller DTRs, the existing DT can be installed on a prefabricated foundation with a single LBS and LT panel, controlled in groups.

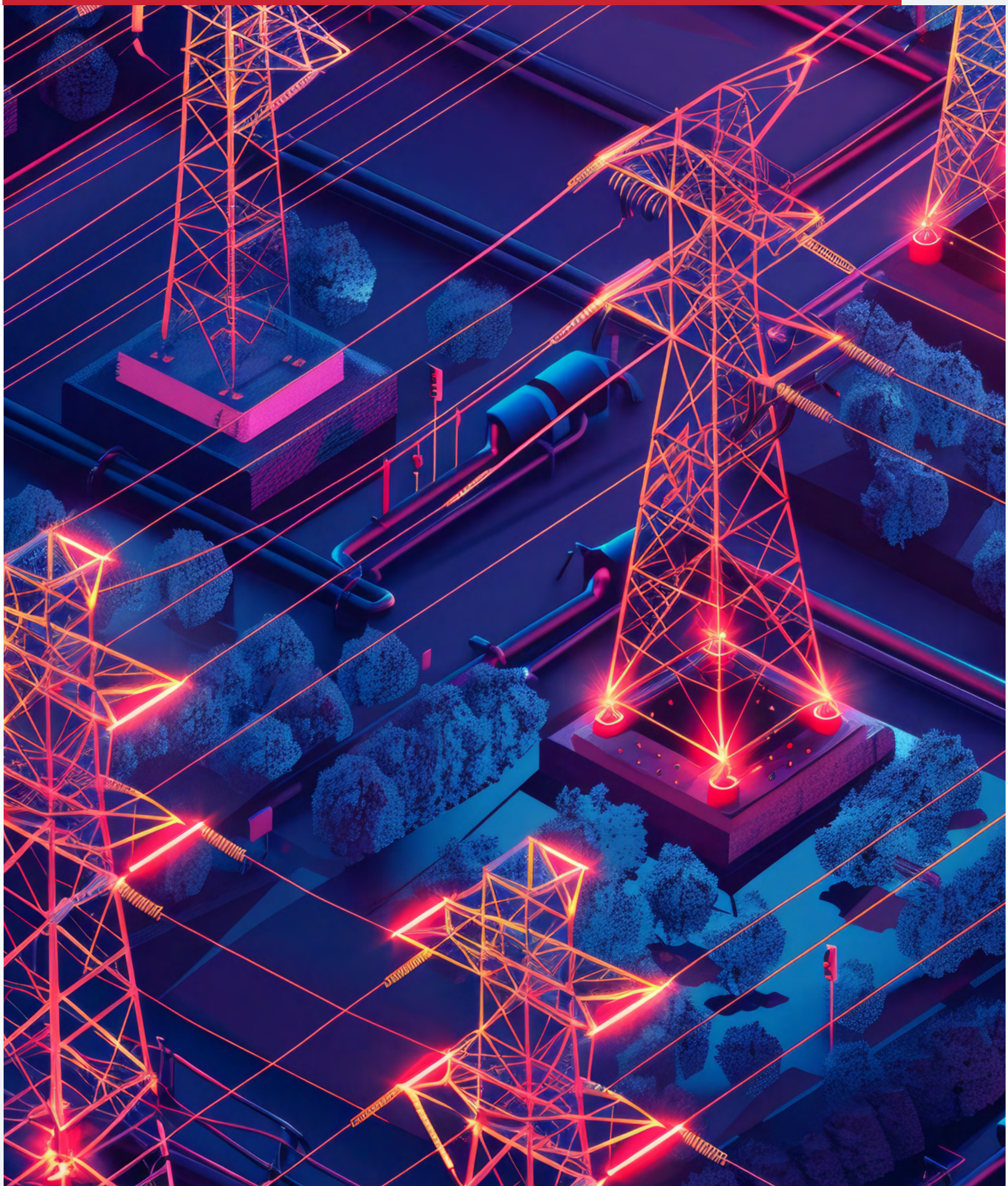
(c) 33/11kV Substation Renovation

Outdoor substations are vulnerable to cyclones and floods and need to be renovated to address wind zones and their severity. One proposed solution is to replace the outdoor Joist pole structures with H-type pole structures. In flood-prone areas, the transformers' plinth should be elevated above the defined flood level (DFL). In some cases, substation switch yards have been completely submerged under floodwater, reaching up to an average height of 2.00 m. Thus, it is essential to implement measures to fortify the substation equipment structures and foundations to withstand increased wind velocity of roughly 260 km/h and the HFL condition.

Therefore, the lattice structures must be designed to accommodate these two conditions:

- To withstand increased wind velocity for areas never inundated by flood water.
- To withstand increased wind velocity for areas inundated by flood water up to approximately 2m average height.

8 TECHNOLOGY AND INNOVATION



8 TECHNOLOGY AND INNOVATION

8.1 Current Materials, Technologies and Designs being used in Odisha

Baseline Assessment

While standards, codes and regulations are integral in establishing a framework for the functioning of the entire T&D infrastructure system, it is essential for the power sector, particularly across vulnerable geographies, to explore advanced technological solutions and innovations to meet specific targets and goals.

The baseline assessment report (i.e., Essential Guide to Disaster Preparedness, Survival and Community Resilience) involved a comprehensive analysis of current technologies, materials and designs employed in Odisha across three disaster stages: pre-, during and post. Through extensive desk research, the project team compared these with their international counterparts.

The team examined various technologies and their implementation in Odisha, as listed below:

- Early warning dissemination systems (EWDS)
- Satellite phones
- Emergency restoration system (ERS) towers
- Underground cabling system for T&D systems
- Ring main units (RMU)
- Compact secondary substations
- Rebar lacing poles (RLP) and H-type pole for distribution system
- RCC spun poles
- Indoor gas insulated substations PSS and grid substation (GSS)
- E-house 33/11kV gas insulated substations PSS
- Automatic fault analysis system (AFAS)

8.1.1 Early Warning Dissemination Systems

The primary purpose of EWDS is to establish a reliable communication system to bridge the existing gap in disseminating disaster warnings up to the community level. This will be achieved by strengthening the State Emergency Operation Centre (SEOC), District Emergency Operation Centre (DEOC) and Block Emergency Operation Centre (BEOC). The aim is to ensure that information is effectively disseminated from the state, district and block levels to communities and vice versa. Ultimately, the objective is to ensure that even the last person living nearest to the sea is well-informed and able to take appropriate action in the event of a disaster.

Overall, a total of 1,205 villages in 22 blocks of six coastal districts (Balasore, Bhadrak, Jagatsinghpur, Kendrapara, Puri and Ganjam) of the state have been identified as high priority areas for disaster preparedness. These areas are prone to diverse hydro-meteorological disasters such as cyclones, floods and tsunamis, posing a significant risk to the lives and properties of vulnerable inhabitants. Odisha has been a pioneer in implementing the EWDS, ensuring that even the most remote residents can receive timely alerts about impending disasters.

The technology of EWDS is as follows:

- Integrating different technologies to effectively disseminate disaster warnings on a single platform to reach the last mile to the communities and fishermen in the sea

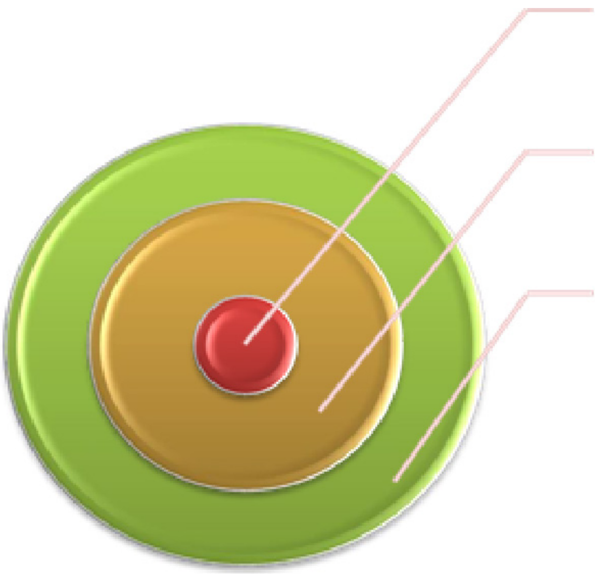
- The technology involves satellite-based mobile data voice terminal at the SEOC and six DEOCS. It features digital mobile radio (DMR) connectivity to the SEOC, six DEOCs, 22 BEOCs and 14 FLCs. Additionally, there are alert towers at 122 locations within 1.5 km of the coastline to facilitate both cyclone and tsunami warning dissemination. The SEOC also utilizes mass messaging for SEOC for cyclone and tsunami alerts, along with a universal gateway to ensure interoperability among the various systems.

The technology and system in place are highly reliable for early warning dissemination. It will work 24/7 and will not fail under any circumstances (Source: https://OSDMA.org).

8.1.2 Warning System for DISCOMs

In the current setup, Odisha State Disaster Management Authority (OSDMA) has developed an early warning system and by detecting an incident, warnings and communications are given to the respective responsive personnel and teams. However, DISCOMs are planning to implement 'Siren Codes' for the warning system, as shown in Figure 8.1.

Figure 8.1: Warning system for DISCOMs



8.1.3 Satellite Phones

Communication plays an integral role in disaster management. During the response and recovery phases, having reliable information and communicative means becomes even more critical. All conventional methods of communication, including land phones and cell phones, which rely on terrestrial networks, can often fail during and post-disaster. Moreover, most mobile telephone networks operate close to capacity during normal times, and large spikes in call volumes caused by widespread emergencies often overload the system when needed the most. In these situations, the satellite phone or satphone operates directly through geo-stationery satellite and, therefore, can avoid this problem and provide failsafe communication in any eventuality.

OSDMA has 58 INMARSAT handheld ISAT Satellite Phones, strategically distributed among key disaster managers at both state and district levels. These officers can move to the disaster site with the satellite phone and restore connectivity if other modes of communication have been disrupted or unavailable.

- All 30 district collectors have been provided with INMARSAT ISAT handheld satellite phones.
- Two INMARSAT ISAT phones to 10 ODRAF units have been provided.
- One INMARSAT ISAT handheld satellite phone has been set up in the state emergency operations centre in the office of the special relief commissioner.
- One INMARSAT ISAT handheld satellite phone provided to the police commission and fire service
- Five sets are kept with OSDMA and will be provided to the Chief Minister and Chief Secretary Office during any disaster or disruption of terrestrial communication.

(Source https://OSDMA.org)

8.1.3 Emergency Restoration System (ERS) Towers

Odisha Power Transmission Corporation Limited (OPTCL) is using ERS towers for restoration to extend the power temporarily till the damaged towers are reconstructed. As per the disaster management plans report of OPTCL, it has 42 units of 220kV towers, two units of 400kV towers (old design) and 12 units of 400kV towers (new design), and ERS towers stored in different locations for use during disasters. During disaster events, all responsible personnel have been instructed to ensure the availability of necessary tools and tackles (welding/cutting sets, chain pulley blocks, ropes, water pumps, diesel generators, etc.) and trained operators. However, there remains a vast gap in providing the new technology support or system for quick restoration.

ERSs are innovative modular aluminium towers designed to quickly restore power on damaged power transmission lines while minimizing disruptions for scheduled maintenance work with minimal power interruption. These temporary structures can be erected in two to three days instead of the several weeks required to restore the towers permanently. The importance of ERS has grown in response to the rising number of tower failures in recent years. The movement towards standardizing ERS began internationally in 1982 in the USA, with IEEE guidelines established by 1995, a framework that many other nations have since embraced. However, India has yet to develop its own ERS solutions. While ERS technology is available in Western and other developed countries, it is patented and often comes with substantial procurement costs.

8.1.4 Indoor Gas Insulated Substations PSS and GSS

OPTCL and DISCOMs have installed many gas insulated substations GSS and PSS in their region, mostly indoors and highly resilient to cyclones. A few gas insulated substations are also under construction in Bhubaneswar City and its peripheral area.

8.1.5 E-house 33/11kV Gas Insulated Substations PSS

Figure 8.2: E-house at Unit-2, Bhubaneswar under TPCODL

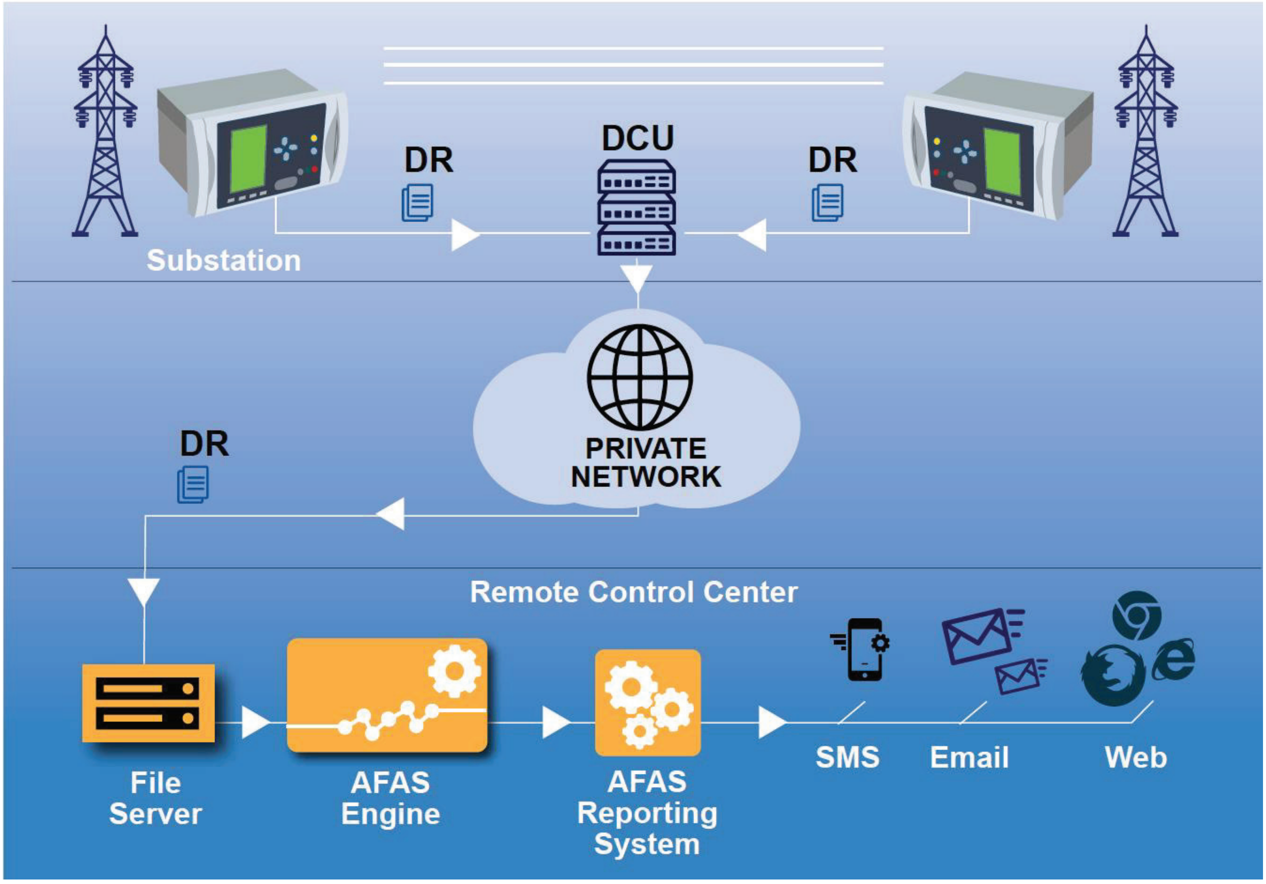
Eleven e-houses operate across four DISCOMs of Odisha, with nine located in coastal districts. The 33/11kV PSS technology is entirely cyclone resilient and primarily utilized in urban areas, requiring less space for installation. The cost of this type of PSS is very high as compared to conventional AIS PSS. See Figure 8.2 showcasing the 33/11kV gas insulated substations PSS and Figure 8.5 presenting an E-house at Unit – 2, Bhubaneswar, under TPCODL.

8.1.6 Automatic Fault Analysis System

OPTCL is one of the largest transmission utilities in the eastern region, having an extensive and complex transmission network. In case of any fault in the line or substation, immediately providing information to the concerned officers regarding the location or type of fault takes a lot of time, which increases the outage time. AFAS is one of the latest developments that helps the O&M team find and analyze faults quickly. This technology is successfully operating in power grid networks across the country. As the power supply in the coastal region of Odisha is getting disrupted very frequently due to saline effect and strong wind, OPTCL is in the process of implementing AFAS in all those substations along the coastal zone in the first phase for quick fault finding and also quick restoration of power supply.

Disruptive innovations in protection and communication technologies and intelligent protection systems generate voluminous data. Most of the progressive utilities around the globe have invested heavily in building this kind of infrastructure as part of their substation automation.

Figure 8.3: Automated fault analysis system architecture



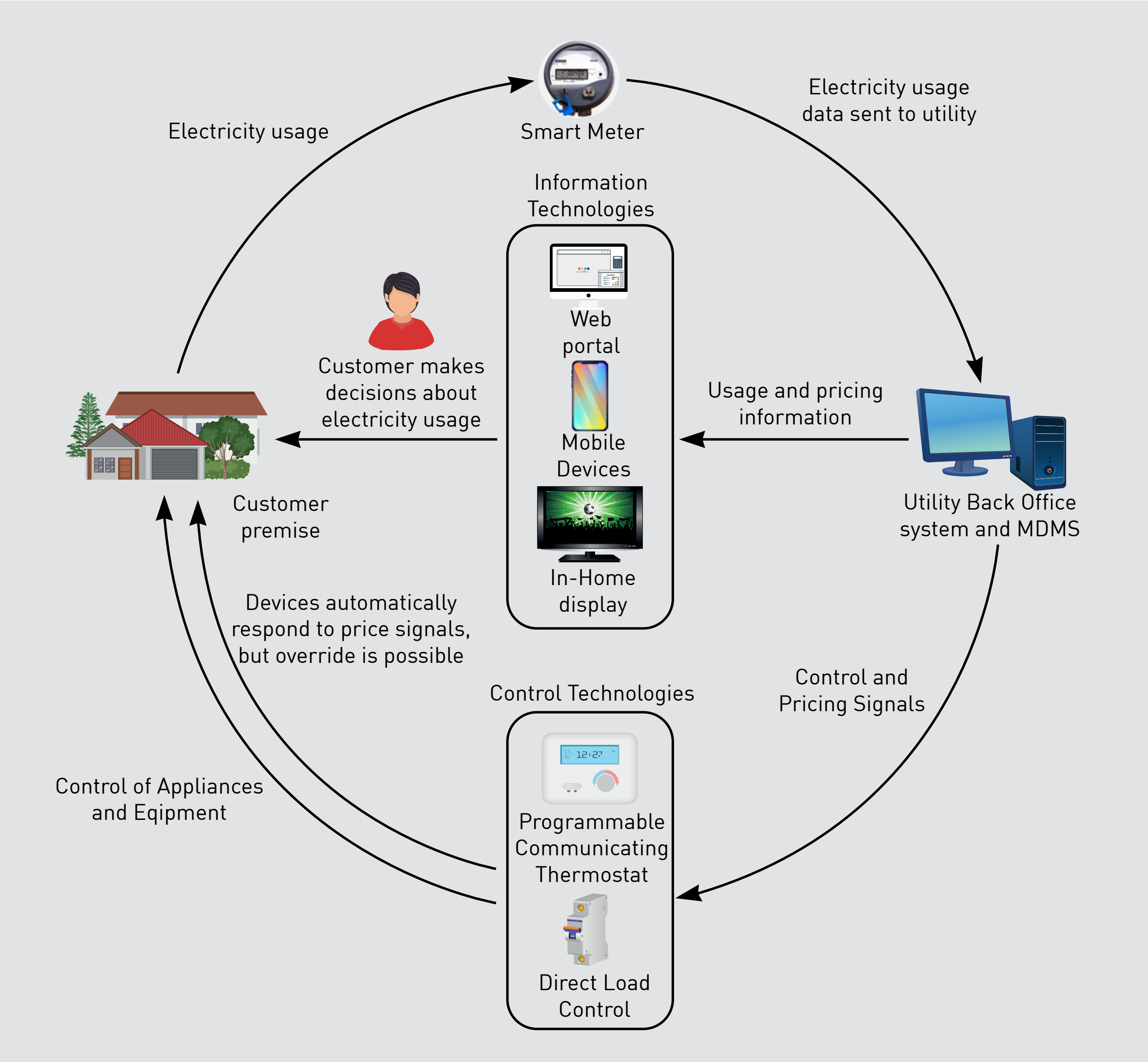
AFAS completely automates fault analysis and provides concise information in minutes, enabling faster decision-making and reducing operational costs (see Figure 8.3 for AFAS architecture reference). AFAS is equipped with the intelligence to validate and analyze the disturbance record (DR) files recoded by intelligent electronic devices (IED) during fault conditions.

Based on the analysis of the recorded current and voltage waveforms and digital signal information stored in the file combined with a detailed network model, AFAS analyzes the fault and automatically generates a detailed report of the fault condition indicating fault attributes and sequence of events. AFAS streamlines the process of timely analysis of the disturbances and generates comprehensive notices that comply with utility standards, providing deep insights into fault behaviour.

8.1.7 Advanced Metering Infrastructure

Today, DISCOMs have started replacing conventional meters with smart meters. Advanced metering infrastructure (AMI) is an integrated system of smart meters, communications networks and data management systems that enables two-way communication between utilities and customers. The system provides several vital functions that were not previously possible or had to be performed manually, such as automatically and remotely measuring electricity use, connecting and disconnecting service, detecting tampering, identifying, and isolating outages, and monitoring voltage. With customer technologies like in-home displays and programmable communicating thermostats, AMI also enables utilities to offer new time-based rate programmes to reduce peak demand and manage energy consumption and costs.

Figure 8.4: Advanced metering infrastructure architecture



AMI became an important contributor to outage management, service restoration and voltage monitoring for many SGIG projects, particularly those that implemented AMI alongside investments in distribution automation technologies (see Figure 8.4 for AMI architecture reference). With AMI, utilities can isolate outages faster and despatch repair crews more precisely, reducing outage duration, limiting inconvenience, and reducing labour hours and truck rolls for outage diagnosis and restoration. Utilities facing regular, severe weather events and storm-induced outages have greater incentives for using AMI for outage management than those without.

AMI data integration with other information and management systems, including outage management systems (OMS) and geographic information systems (GIS), enabled utilities to create detailed outage maps and, in some cases, post these maps on utility websites to keep the public informed on service restoration progress.

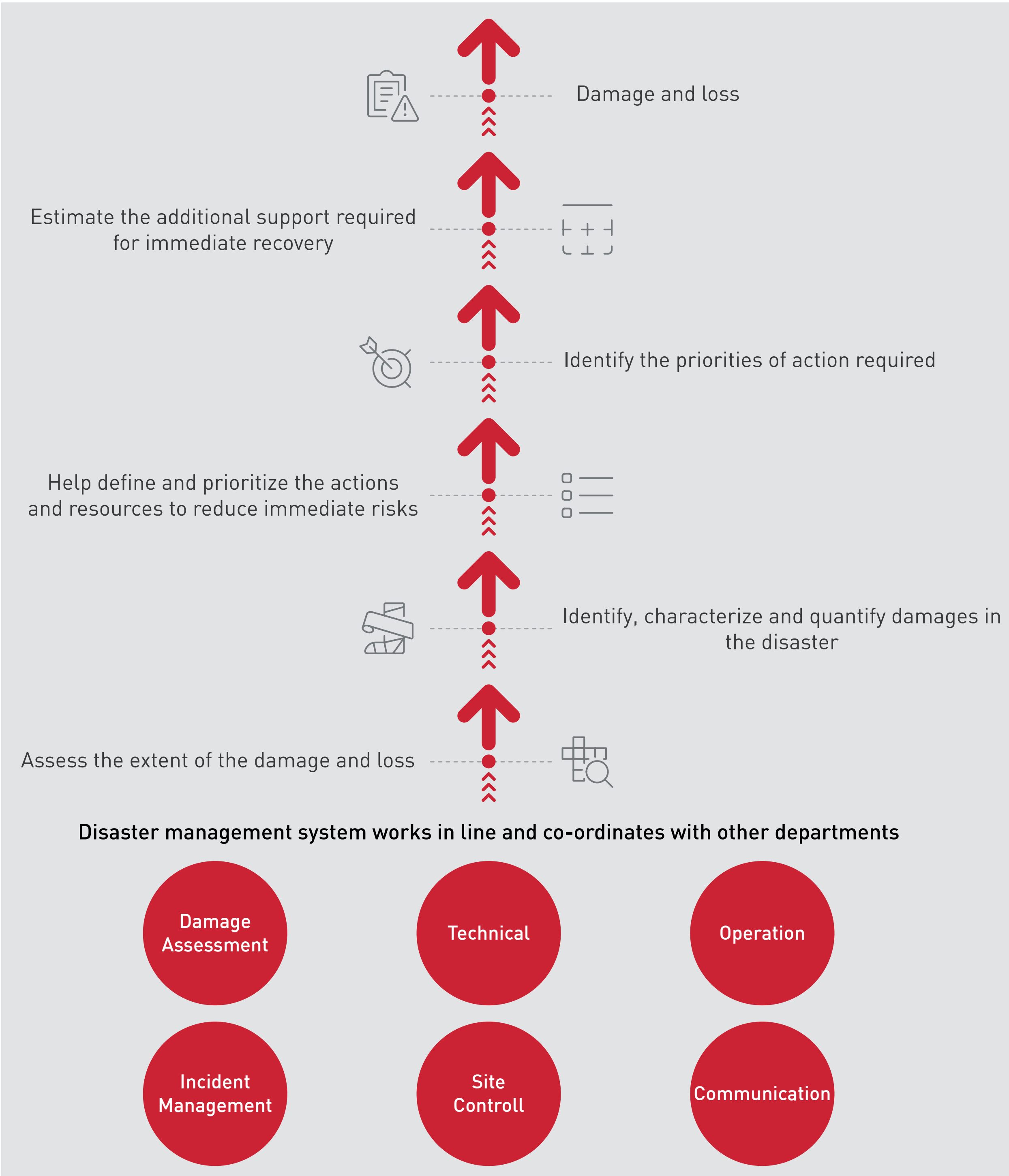
Additionally, voltage monitoring provides another promising benefit stream that can be included in a business case analysis of AMI investments. Utilities can use AMI voltage monitoring capabilities to enhance the effectiveness of automated controls for voltage and reactive power management, particularly for conservation voltage reduction (CVR) programmes.
(Ref: https://www.energy.gov)

8.2 T&D Monitoring and Post-Disaster Restoration

Distribution companies deploy vehicles to conduct on-site verification to monitor power infrastructure. When an event occurs, the damage assessment team quickly heads to the locations to evaluate the extent of damage inflicted. Figure 8.5 illustrates the responsibilities and roles of the assessment team.

Disaster management system works in line and coordinates with other departments.

Figure 8.5 T&D monitoring and post-disaster restoration



After the damage assessment team shares the report with the technical team, it identifies, characterizes and quantifies the damages, and decides on the resumption plan operation. Once finalized, the operation team executes the recovery plan finalized by the technical team and reports the status periodically. While the damage assessment, technical and operation teams are working, the rest are on alert for a possible activation of the continuity plan. The role and responsibilities of each team are clearly defined, and the teams act accordingly. However, T&D companies face significant obstacles in clearing debris caused by fallen trees. Teams often must use ladders for physical clearance or may call in third-party contractors. In cases where access is challenging due to dense forest or large fallen trees, transmission companies enlist the aid of the ODRAF team to help clear the route.

In recent years, significant efforts have been made in the T&D sectors to address the critical challenges posed by repeated cyclones in Odisha, especially in the coastal region.

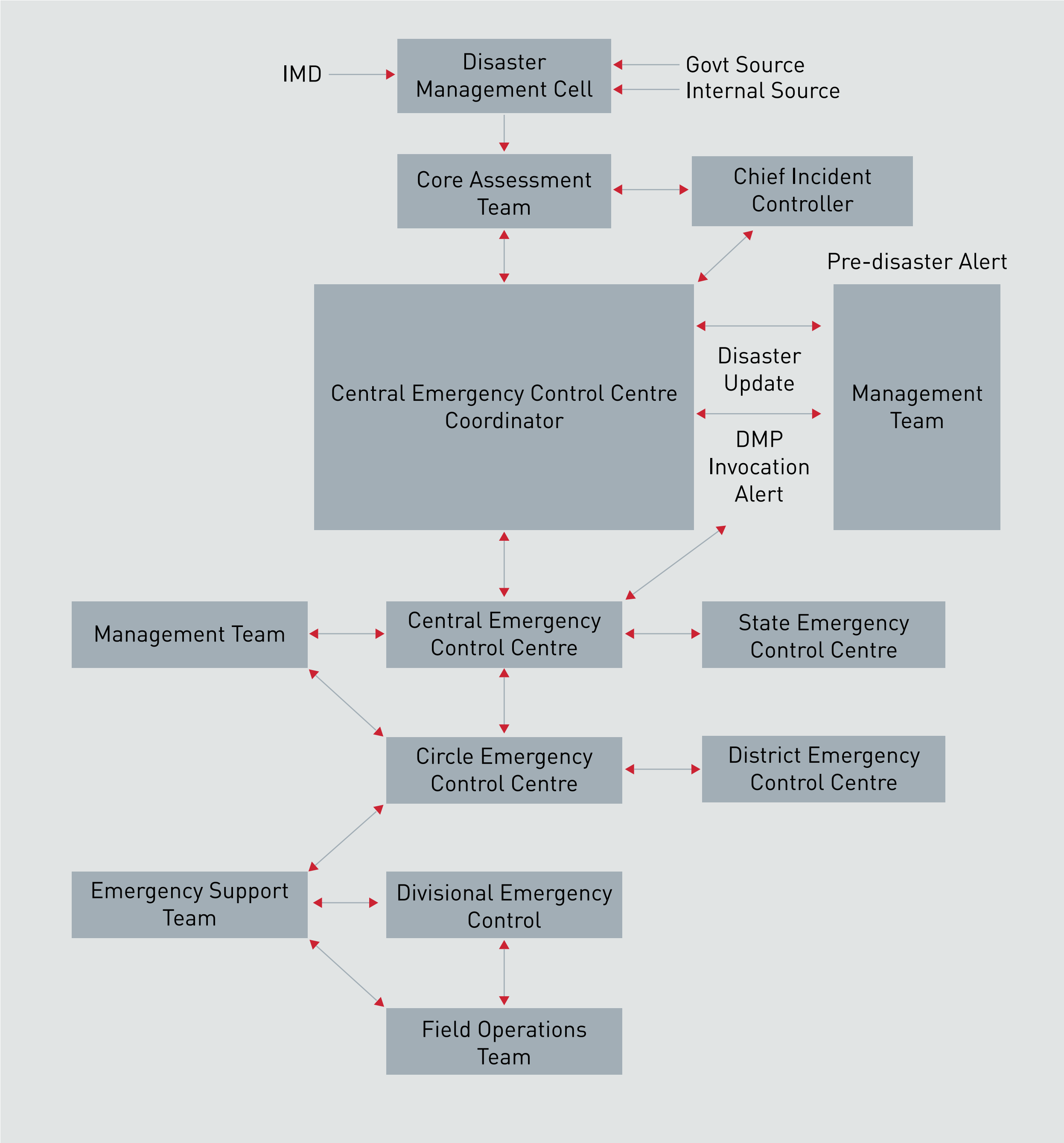
OPTCL has focused on strengthening grids and lines using various advanced technologies such as tower design as per Wind Zone VI network reconfiguration from radial to ring system, and replacement of ACSR conductor by HTLS conductors to carry more loads during contingencies. This includes laying of EHV cables in place of OH lines and installing gas insulated substations grids in place of AIS grids in cyclone-prone areas. The implementation of supervisory control and data acquisition (SCADA) and AFAS systems allows for remote operation and monitoring for quick fault finding and restoration. It also enables stocking adequate ERS towers for the restoration of power supply immediately after the cyclone. The Government of Odisha has invested substantial funds for constructing gas insulated substations GSS and PSS in the coastal region within the last five years.

DISCOMs have introduced RLP poles by TPCODL for distribution lines in coastal regions, capable of withstanding wind speeds up to 300 km/h. TPNODL uses spun poles in the coastal region. Efforts to convert overhead lines to an underground cabling system have been undertaken alongside network reconfiguration from radial to a ring system. Further developments include installing gas insulated substations PSS, E-house, Compact DTs and RMUs. The adoption of AMI and Smart metering, coupled with the implementation of a SCADA system to connect all PSS enhances remote monitoring during disaster.

8.3 Current Practices for Information Flow

In the T&D system, it is crucial to assess the risk before any disruptive incidents like cyclones or floods. To do this, the T&D companies follow the IMD instructions to analyze the risk and prepare for any contingency. Currently, there is no specific early warning system developed or used by the utilities to assess or monitor the hazards. However, OPTCL and DISCOMs have established their own disaster management system in place to prepare for disaster mitigation. The risk assessment process used by DISCOM systematically identifies, analyzes and evaluates the risk. The information flow of DISCOMs during a disaster is shown in Figure 8.6.

Figure 8.6: Information flow under DISCOMs



The DM plan of DISCOMs clearly outlines the roles and responsibilities of each department and team, ensuring a systematic response to disaster events.

9 Global Technologies for Risk Mitigation and Gap Identification

9 Global Technologies for Risk Mitigation and Gap Identification

9.1 Global Technologies for Risk Mitigation and Gap Identification

A technological revolution has emerged in the ever-evolving power sector landscape, reshaping how utilities manage disruptions and restore services. At the heart of this transformation are two critical systems: the outage management system (OMS) and the geographic information system (GIS). Together, they form the backbone of modern power infrastructure, providing utility operators with real-time situational awareness and control.

GIS, with its map-based database, has emerged as the cornerstone for documenting the distribution system. Its ability to track geographically dispersed assets and monitor their status in real-time empowers operators to prioritize areas for repair. Integrating GIS with operational data from field applications and live supervisory control and data acquisition (SCADA) creates a dynamic asset management system that offers rapid insight and understanding.

The use of mobile applications linked to GIS further enhances operational efficiency. These apps facilitate damage assessment by providing operators with crucial information about the cause of an outage, impacted assets and the extent of damage. With features like image capture and automatic upload to GIS, the system has revolutionized incident management and response, allowing for quicker decision-making and resource allocation.

The live updating of GIS has become a collaborative tool and work plans are optimized based on real-time data, improving decision-making for subsequent technical disciplines. This seamless flow of information from the field to the control centre ensures a swift and effective restoration process.

Moreover, integrating mobile apps for installation and operational maintenance adds another layer of sophistication. By leveraging computer and smartphone technologies, these apps retrieve real-time data from GIS when pointed at distribution equipment. Field crews can access relevant information such as drawings and circuit overviews, enabling them to tag equipment for repair and estimate restoration times.

9.1.1 Global Technologies

Based on global technologies used for power infrastructure resilience, a benchmarking analysis is developed, including key gaps in the process. The benchmarking analysis briefly covers the novel approaches adopted by other tropical countries facing similar climatic risks in the power infrastructure sector. Some examples of global cases where definitive steps have been taken for risk mitigation are given below:

Tonga, facing significant risks from cyclones, has taken steps to modernize its electrical infrastructure. This includes replacing its low-voltage overhead network with aerial-bundled conductors (ABCs) and installing underground service cables to customer premises and new smart meters. These upgrades aim to enhance technical performance by minimizing losses and outages while also bolstering resilience to hazards When Tropical Cyclone Gita made landfall in Tongatapu, Tonga, an estimated 54 percent of the network had been upgraded. The impact was evident, as the cyclone caused damage to 45.9 percent of the power grid that had not been upgraded, compared to only 4.7 percent of the upgraded segments of the grid (Stronger Power 2018).

Composite utility poles, smart grid technology, vehicle-to-grid, mobile transformers and substations, truck-mounted mobile emergency generators (MEGs), wireless power transmission, phasor measurement units, automated switches, Cloud VMS, smart switches, dynamic line rating, gas-insulated lines and virtual power plants are some of the global technologies which becomes useful not just in daily operations but also in disaster management. The following sections would briefly describe some of these technologies.

Unmanned Vehicles

Some utilities have begun using unmanned aerial vehicles (UAVs) or drones equipped with high-resolution cameras, sonar and laser data measuring devices, thermographic imaging and global positioning systems to complete routine checks on transmission lines. These UAVs can be valuable tools for assessing damage following meteorological and geological events. Lightweight and easy for a technician to manage, UAVs enable rapid surveys of hard-hit areas that may be inaccessible due to blocked roads from fallen trees or other debris. This capability significantly reduces response times—potentially by hours or even days—while also lowering costs.

Unison Networks in New Zealand conducted field trials to assess the commercial viability of UAVs to monitor distribution and sub-transmission infrastructure. They discovered that while small UAVs have a high marginal cost per kilometer and are typically more expensive than linesmen, larger UAVs that can fly beyond line-of-sight can provide substantial cost savings. Trans-power NZ had similar findings. In addition to reduced operational costs, it is estimated that consumers could see annual benefits between NZ$ 4.46 million and NZ$ 19.26 million due to fewer and shorter outages in the distribution systems (Shelley and Andrews 2015).

Case Study: UAV Surveys following Cyclone Pam

When Cyclone Pam hit the small Pacific Island nation of Vanuatu in March 2015, thousands of buildings and trees were flattened, leaving 75,000 people displaced and at least 15 dead. The World Bank contracted two teams to conduct UAV surveys of the devastated area. One team from Australia used Indago quadcopters (four-rotor helicopters), while a team from New Zealand used three Alliance hexacopters (six-rotor helicopters). Within 12 days, a single quadcopter was able to survey 2,500 acres of an island. It was able to fly in winds of up to 40 knots or in moderate rain, with low cloud cover weather conditions that would have grounded more traditional aircraft. See Figure 9.1 for UAV (Drone) on patrol.

The UAVs were pre-programmed for their routes, so they essentially acted as flying robots. They enabled quick data gathering of infrastructure and building damage down to the household level and in difficult-to-access locations. The aerial views promptly provided rich information sources whose collection would have been constrained using normal ground surveys.

Figure 9.1: Unmanned aerial vehicle (drone) on patrol

- Various transmission companies have trialed large UAVs for routine transmission line patrols. Substantial cost savings have been proven.
- These large UAVs can be programmed with GPS coordinates and transmission line routes, allowing them to operate beyond the visual line of sight. Some have operated on the order of 1,000 km in a single trip.
- However, in most countries, the use of UAVs remains restricted due to underdeveloped airspace management and regulatory frameworks regarding their operation.

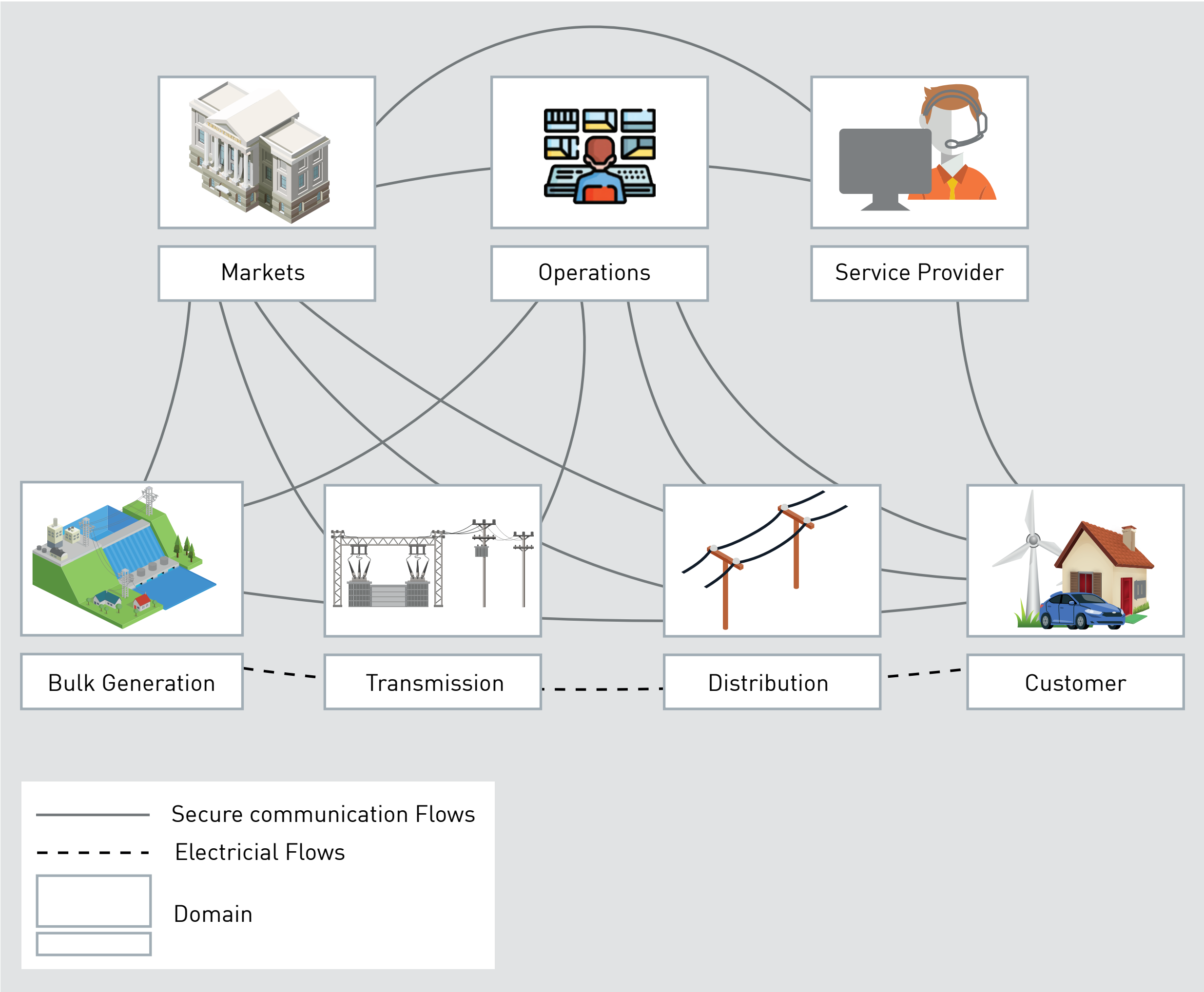
Smart Grids and Innovations

Smart grid projects integrate data from advanced metering infrastructure (AMI) systems with OMS and geographic information systems (GIS). These systems give grid operators and repair crews information on outage locations and the extent of customers affected by the outages. These systems accelerate mass outage responses by focusing restoration efforts on repairs that will get power to most customers as quickly as possible, with lower costs from more efficient operations and a lesser requirement for field staff. Thus, with the increased flexibility feature, the smart grid can help reduce the impact of climate change on critical infrastructure.

Microgrids can separate themselves from the utility seamlessly during a grid disturbance. Then, when the utility grid returns to normal, the microgrid automatically re-synchronizes and reconnects to the grid equally seamlessly.

A smart grid is an automated intelligence empowered by information and communication technology (ICT) and a widely distributed energy delivery network. A two-way flow of electricity and information characterizes it. The system can monitor and respond to changes in energy supply and consumption in the network. Smart grids and AMI improve situational awareness and facilitate rapid service restoration. See Figure 9.2.

Figure 9.2: Smart grid operation



Application and Benefit of Smart Grid

The areas of application of smart grids include smart meter integration, demand management, smart integration of generated energy, administration of storage and renewable resources, and using systems that continuously provide and utilize data from an energy network.

A smart grid would have the following:

- Automatically detects and responds to routine problems and quickly recovers if they occur, minimizing downtime and financial loss.
- It (Generation, Transmission, Distribution) has an advanced two-way communications system.

- It enables real-time monitoring and control.
- It provides greater visibility and transparency.
- Consequently, it allows cost reduction and efficiency improvement.

In 2007, the USA established a national Smart Grid Energy Independence and Security Act (EISA) policy. The Act assigned NIST (National Institute of Standards and Technology) the primary responsibility of coordinating the development of standards for the smart grid.

The US Smart Grid goals include the following:

- Increase system efficiency and cost-effectiveness.
- Improve reliability, resiliency and power quality.
- Provide customers with tools to manage energy use.
- Enable innovative technologies, including renewables, storage and electric vehicles.

Phasor Measurement Units

PMUs have averted widespread blackouts even in everyday operations. They rapidly assess and report the state of the transmission network and when employed in wide-area monitoring systems, automatically react to changes in the network.

The information from PMUs and other intelligent electronic devices helps improve grid performance and resilience and is vital to system operators, who are otherwise blind to rapid changes in the power system. Meanwhile, advanced metering infrastructure provides two-way communication, which helps utility companies improve situational awareness.

Automated Switches

They enable quick network reconfigurations and easy fault isolation, preventing entire feeders from tripping. As they do not require manual replacement, replacing traditional fuses with automated switches can significantly improve network adaptability while reducing costs.

Smart Meter

Figure 9.3: Smart meter

A smart meter (refer to Figure 9.3) is an electronic device capable of recording energy consumption and communicating with the utility for monitoring and billing. It is a combination of smart meters, smart concentrators (or eventually gateways), information technology (IT) and two-way communication systems.

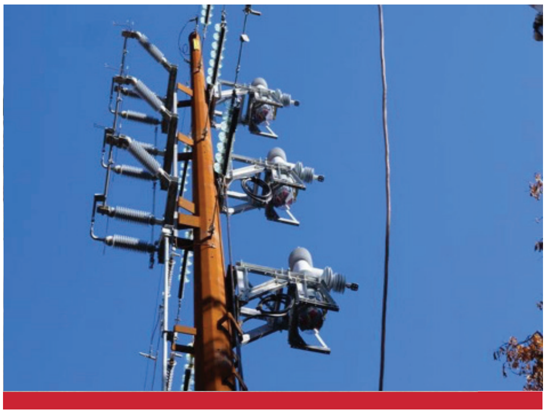
Smart metering is a major building block towards implementing smart grid, which utilities are actively working towards. A smart grid uses high-performance communications, advanced sensing and enterprise analysis to transform the existing electric grid into a dynamic, self-healing, self-optimizing transmission and distribution system.

The advanced metering technology has the potential to provide benefits to all key stakeholders along with electricity generation, distribution and consumption chain, including end customers. DISCOMs are already implementing Smart meters in Odisha.

Sub-Transmission Recloser

High-voltage pole-top recloser supports faster overcurrent protection through fault isolation and automatically restoring service during temporary faults on overhead sub-transmission lines. G&W Electric, a global supplier of electric power equipment, developed its Viper-HV recloser up to 72.5kV. This high-voltage pole top recloser supports faster overcurrent protection through fault isolation and automatic restoration for temporary faults on overhead sub-transmission lines. See Figure 9.4 for the sub-transmission recloser.

Figure 9.4: Sub-transmission recloser

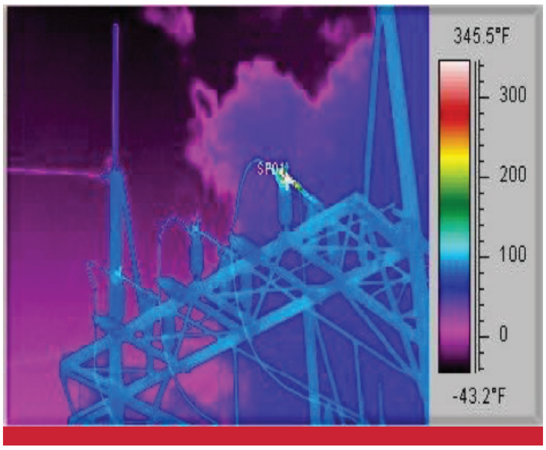


Infrared Thermography Power Line Inspection

Utilities can use infrared technology to scan and identify problems with transmission lines and other electrical equipment. When components of electrical systems begin to fail, a common symptom is a significant temperature difference between ailing components and their surroundings.

Using infrared technology (see Figure 9.5), utilities can perform fast and efficient preventative maintenance on large areas of transmission circuits.Routine infrared scans of critical equipment can help avoid emergency restoration efforts by identifying problems before they escalate into failures.

Figure 9.5: Infrared technology



Smart Switches

Electric utilities are not only making their systems more resilient through a focus on system hardening and vegetation management, but they are also rolling out new technologies to expedite restoration. For example, "smart switches" enable system operators to isolate power outages and remotely reroute power from another source within minutes.

In addition, smart switches automatically restore power to customers when a tree limb temporarily contacts wires and help protect the electric system when a problem is detected. Also, optical ground wire (OPGW) enhances communication between company facilities and protects the high-voltage transmission system from severe weather conditions, such as lightning strikes.

Moreover, smart circuit technology is employed to facilitate faster restoration by accurately locating faults and enabling automatic reconnection of customers outside the affected area.

Mobile Transformers and Substations

Figure 9.6 Mobile substation and transformer

Mobile transformers and substations (see Figure 9.6) can be used by utilities to temporarily replace substation transformers in the low and medium power range (10-100 MVA), following a hurricane.

Mobile substations include the trailer, switchgear, circuit breakers, emergency or station power supply, a compact high-power-density transformer and enhanced cooling capability. They enable the temporary restoration of the grid service by circumventing damaged substation equipment, allowing for necessary repairs to take place. In some instances, these mobile transformers can be operational and restore the flow of electricity within 12-24 hours.

Mobile Generator

Truck-mounted mobile emergency generators (MEGs) are critical flexibility resources of distribution systems (DSs) for resilient emergency response to disasters. However, they are currently under-utilized. To optimize their usage, it is crucial to recognize that the travel time of MEGs on road networks (RNs) significantly affects the duration of outages for critical loads. Implementing a two-stage dispatch framework that includes pre-positioning and real-time allocation can greatly improve efficiency in emergency situations.

In recent years, extreme weather events have frequently occurred, causing significant economic losses to society. For example, the devastating earthquake and tsunami in Nepal and Chile in 2010, caused loss of power supply to many customers for several consecutive days. In 2012, Hurricane Sandy resulted in blackouts affecting 8 million customers, with an estimated loss of US$ 75 billion. In 2017, Hurricane Harvey caused an outage of 10,000 megawatts in Texas, affecting 291,000 customers.

To address these challenges, there has been a growing reliance on electric vehicle fleets, mobile energy storage (MESS) systems, electric buses and emergency generators, which are widely used as mobile power (MP) sources. One proposed solution for restoring power to critical services involves deploying MEGs in the distribution system to restore critical loads by forming multiple microgrids. These MEGs can operate independently of primary substations during disasters, effectively serving as a backup supply. However, the significant investment required for MEGs means that the primary focus should be on minimizing the economic losses associated with power outages.

Composite Utility Poles

Figure 9.7: Composite poles

Composite utility poles (see Figure 9.7) are made from fibreglass-reinforced polymer composite material. They provide an alternative to traditional wood, steel, or concrete poles and have several advantages over other materials. The composite poles present several key advantages:

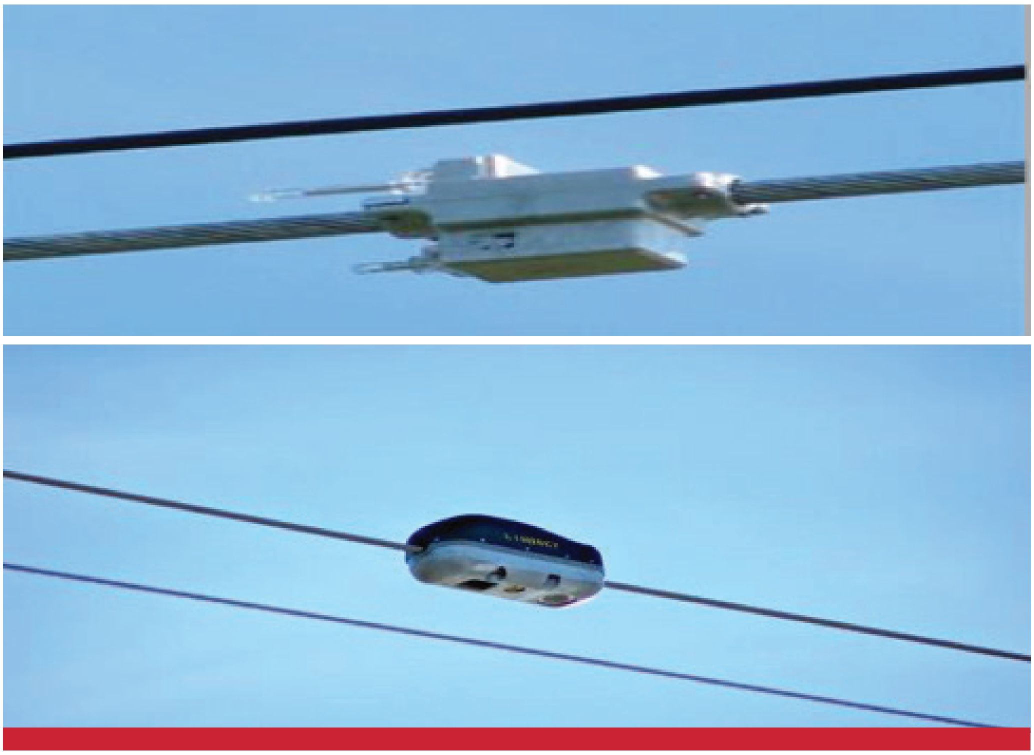
- Light
- More impact-resistant
- Resistant to rot or decay
- Free of toxic preservatives
- Non-conductive
- Virtually maintenance free
- Cyclone resilient

A specific advantage of composite poles over steel poles for coastal regions is that they are corrosion resistant and will not rust. Although composite poles have existed for many years, cost and susceptibility to ultraviolet light have prevented their widespread commercialization. In recent years, however, material costs have come down due to advances in fibreglass technology and ultraviolet issues have been addressed by advances in polymer chemistry. Typically, composite poles have typically been used for distribution lines. Now, even composite poles (70-to-80-foot-tall poles) are also becoming available for transmission lines. Such poles are cyclone resilient and are increasingly popular across the United States.

Dynamic Line Rating

The dynamic line rating (DLR) of OHL leverages the principle that their ampacity (see Figure 9.8 for reference) is influenced by surrounding ambient conditions, with these lines originally designed to handle extreme summer heat. As less severe weather conditions exist for most of the year, the ampacity of the existing lines can be significantly increased (up to 200 percent). The major task thereby is to derive the present and forecast the future ambient conditions, calculate the current carrying capacity, and integrate these results into despatch centre processes, considering adequate security margins.

Figure 9.8: DLR in power lines



Typical Applications

- Check the ability of OHL and equipment in substations to carry higher currents.
- Improves economic despatch scenarios in N-1 contingencies.
- Integrates renewable/distributed energy sources without grid reinforcement.
- Defer or avoid uprating circuits.
- Maximize the use of alternate lines when main corridors are undergoing maintenance.
- Addresses potential safety/conformance issues.
- Checks the clearance to define the maximal allowable temperature/line capacity.
- Identifies line hot spots for monitoring installation.

OMS, GIS and SCADA

The Outage Management System (OMS) and Geographic Information System (GIS) are the central core business functions for modern power disruption restoration activities of T&D utilities. These vital systems enable command centre operations to access and understand real-time situational information.

GIS has become the foundation of distribution system documentation because its map-based database is ideally suited to tracking geographically dispersed assets and monitoring their status. By keeping the GIS database up to date in real-time, operators can prioritize areas of the network to target for repair, and crew despatchers can monitor progress. As a geographically and visually based asset management system linked with operational data from field applications and live SCADA, GIS provides insight and understanding that was not previously possible. It also enables simple communication of information to third parties.

Mobile applications designed for damage assessment linked to the GIS assist operators in understanding the cause of an outage, the assets impacted and the extent of asset damage. Image capture and safety issues can be automatically uploaded to GIS and work despatch applications. The real-time updates in GIS are transforming how incidents are managed and responded to. By identifying vital areas like essential services, work plans can be prioritized and optimized effectively. This technology enhances our understanding of the effort required and the available resources and materials. With better quality data, decision-making is significantly improved. When the crew completes asset restoration, they upload the new information, including images, to the work management system. This enables the following technical discipline to work on the faulty assets or the control centre staff to place the assets back into service.

Mobile applications (apps) are increasingly used for installation and operational maintenance. By leveraging computers and smartphone technologies, these systems can retrieve real-time data from a GIS when a user points the mobile device at distribution equipment such as a pole or transformer. Data relevant to the equipment (e.g., drawings, equipment order details and circuit overviews) can be downloaded to the field crew. Recovery crews can then tag equipment for repair and replacement and estimate the time to restore.

The mobile apps enable crew locations, equipment and stock to be tracked so capable teams can be despatched efficiently to problem areas, ideally close to them. When constraints arise, nearby crews can be contacted to assist with staff or equipment. The next phase involves enhancing our real-time network visibility with more switching capabilities. To reiterate, some utilities adopted this practice decades ago; with the improved communication systems now available, utilities are extending their communication networks and visibility and remote network control of their SCADA systems. By linking the SCADA system to the GIS system richer data becomes available. This improved visibility provides better damage assessment, improved work prioritization and scheduling, and improved customer results as more accurate restoration times can be delivered.

Utilities can use advanced metering infrastructure to gather distribution network conditions. By interrogating remote smart meters, utilities can better understand the outage status of network components. Even during a power supply outage, many smart meters can indicate their supply point status by sending a 'last gasp' indication before losing their communication ability and another status indication when power is restored.

Other relatively new means of improving power system visibility include adding PMUs and networked power quality analyzers, and utilizing modern digital protection relays along with their SCADA and monitoring functions. By integrating these technologies with utility WANs (wide area networks), the understanding of a power system's condition and behaviour is improved and, ultimately, the utility SCADA systems.

Further, improved real-time situational awareness and control of grid equipment can enhance the utility's ability to reduce the impacts of major disruptions and speed up restoration efforts. The status indications of individual customers increase the utility's situational awareness, enabling it to personalize messages to individual customers or groups to help them make informed decisions.

9.2 Gaps in the Existing Codes and Standards

Design of Transmission and Distribution Lines

Sag tension calculation: The responsibility for sag tension calculation was initially assigned to the state government as per IE Rules 1956. In the meantime, CEA Safety and Electricity Supply Regulation 2010 has specified that the temperature and pressures shall be as per the relevant Indian Standard for sag tension calculation. Specifically, IS 5613 prescribes that the sag tension calculation should be at 32°C (the average daily temperature) and full wind conditions. Meanwhile, IEC 60826:2017 states that the calculation should use the average of daily minimum temperatures. However, it is observed that during cyclones in Odisha, particularly in October and November, temperatures can drop to around 15°C. This discrepancy challenges the applicability of IS/IEC guidelines. Therefore, it is suggested that the local minimum temperature at full wind pressure (during a cyclone) be considered for sag tension calculation.

Wind map: IS 802 Part-1/Sec-1 and IS 875 outline six distinct wind zones. But IS 5613 Part-1/ Section-1 continues to follow the older classification of three pressure zones since 1985. A revision of IS 5613 is necessary to bring it in line with IS 802 and 875.

Load and Pressure: The ultimate load concept needs to be incorporated in IS 5613 in line with IS 802 Part-1/Sec-1.Wind Pressure: In the distribution system for load calculations, the same wind pressure is considered on both poles and conductors. A two-thirds diameter is considered in the case of circular sections. In the case of transmission systems, the wind pressures considered on tower structures and conductors are different. Further, instead of two-thirds diameter in the case of circular sections, full diameter is considered as per IS 802. To ensure consistency in both instances, revisions to IS 5613 are necessary.

Drag coefficient: IS 802-2015 has been suggested for circular section members due to their lower drag co-efficient. These sections should be utilized for new tower designs.

The design wind speed of 260 km/h has been considered in the study report, based on a k4 factor of 1.3 and Zone-6 instead of Zone-5 as per the maps in IS 802 and IS 875. (198 1.3 = 257.4 km, which has been rounded up to 260 km/h). This should remain in effect until the wind maps in IS 802 and IS 5613 undergo revisions.

Unloaded tension: As per CEA (measures relating to Electric Supply) Regulation 2010, the final unloaded tension at 32°C without external load is to be set at 25 percent. This can be changed to 15 percent for distribution lines, helping to reduce conductor tension during high wind speeds.

Foundation: IS 4091:1979 has stipulated that the depth of the pole's embedment for the foundation should not be less than one-sixth of the total length of the pole above the ground. IS 785:1998 has specified the minimum planting depth for different pole sizes. For poor soil, the embedment depth/foundation size should be more based on the foundation design. However, for all kinds of soils, the minimum planting depth specified in IS 1678 or shown in REC drawings is maintained. It is suggested that the foundations be designed for different types of soils as classified in the CBIP Manual for transmission lines.

RoW for 11kV and LT lines: RoW provisions have been specified for 33kV and above voltage levels in IS 5613 and in the Indian Electricity Act Section-68. However, the same has not been specified for 11kV and LT Lines. The most significant risks to HT (33kV and 11kV) and LT lines arise from falling trees. Hence, RoW provisions for 11kV and LT lines are to be specified in the IS and the Electricity Act.

Angle of deviations: Paragraph 3.3 of IS 785:1998 (Reaffirmed in 2014) states that the transverse direction is the direction of the line bisecting the angle between the conductor and the pole. Hence in cases of a deviation, the angle is to be bisected, and the pole is to be installed along the bisected line.

10 Recommendations

10 Recommendations

10.1 Recommendations from this Study

Supporting structures: Existing Joist poles and rectangular cross-section PSC poles are not suitable in cyclone-prone areas due to their longitudinal weakness. For 33kV and 11kV lines, H-Type poles (joining two channels) are recommended instead of Joist Poles and PSC Poles. LT lines should utilize RCC Spun pole/H-type pole, specifically H-type poles with E 350 grade (490MPa).

It is essential to verify cross arm strengths against the tension generated by larger conductors during wind speeds of 260 km/h. In coastal areas, all steel structures will need to be galvanized with thicker coatings than what is currently practiced.

Double pole structures and guy supports are required at angle points and dead ends as per the REC standards. In locations with space constraints, struts should be installed.

At present, FRP poles are in use for street lighting. Some specially designed FRP poles can be utilized in urban areas on a trial basis.

To retrofit the existing distribution lines, interposing poles will be installed as proposed in tables in annexure The sag tension chart/sag table should be consulted during stringing.

Span length: The span length for new lines to be considered as suggested in the report. However, DISCOMs should be allowed to calculate the span lengths as required.

Foundation: In coastal regions, normal soil conditions are unsuitable for an open-cast foundation. Hence, towers must be supported with pile foundations. As the soil condition is not generally suitable for open-cast foundation, steel poles should incorporate concrete foundations and muffing.

Insulators: In coastal areas, polymer or glass insulators are preferable due to salinity issues. The existing porcelain insulators should be replaced with polymer insulators.

Execution: Proper compression/ torque is to be applied when conductors are crimped or clamped.

Replacement of old Infrastructure: Conductors, hardware fittings and insulators older than 25 years will be tested and replaced suitably in the coastal belt. To avoid rusting, epoxy paints need to be applied on outdoor MS structures.

Across the flood/cyclone-prone areas, outdoor sub-stations will be relocated indoors. Due to the flood zonation map in Component II, Task I, raising outdoor equipment foundations is not feasible considering the DFL. The current PSC/Joist poles will be replaced with H-poles in cyclone-affected areas. Distribution transformers (DTR) below 100kVA will be mounted on H-poles, while those 100kVA and above will be installed on the RCC plinth.

HTLS Conductor: High temperature low sag (HTLS) conductors will be utilized for overloaded lines. Additionally, ACSR conductors will be preferred over AAAC, as ACSR boasts superior mechanical strength.

Vegetation management: For vegetation management, a district-level committee comprising representatives of the District Magistrate, Forest Department, Horticulture Department and the Transmission/Distribution Utility will be established. The committee will review the hindrances caused by any person(s) for tree cutting and suggest remedial actions to the District Magistrate. A third-party audit of vegetation management is to be done by the State Government. The State Government may bear the expenditure for such an audit.

During restoration, it is vital to avoid replacing damaged poles with the same type, which can lead to further failures during cyclones. Future restorations will adhere to the new 260 km/h design standards. For example, damaged joist pole/PSC pole will be replaced by H-Pole in 33kV and 11kV lines and while Spun Poles or H porcelain LT lines will be used as necessary.
Under the ground cabling system, ring main units (RMU), compact secondary substation (CSS), gas-insulated substation and Fault Passage Indicators (FPI) will be implemented in select urban areas.

Solar systems with sufficient storage capacity are a priority. Installation of rooftop PV cells in hospitals, water supply systems, telecommunication towers, collectors and offices, etc., will ensure emergency power supply from solar energy when grid power is unavailable. Supporting structures for photovoltaic cells must be strengthened to withstand high wind speeds and dismantled upon cyclone warnings.

10.2 Unmanned aerial vehicles (UAV)/drones can be engaged on a trial basis to monitor the vegetation growth on both sides of the line. Even the line restoration works can be monitored with a UAV. CEA Recommendations

The k4 factor (1.3) stipulated in IS 15498:2004 (Guidelines for improving the cyclonic resistance of low-rise houses and other buildings/structures), IS 875 Part 3, is to be considered. IS 802 (Part 1 Section 1) for transmission lines does not have this factor. Hence, the k4 factor may be incorporated in IS 802.

The drag coefficient factor on tower members is to be increased in line with IEC 60826:2017.

Wind maps in IS 802 Part 1/Section 1 and IS 875 Part 3 are to be modified since these were prepared with limited wind data up to 1982 and the climate change effects were not considered. As per the maps in CII-I Risk Identification and Estimation, the wind speeds are to be referred to modify the wind map in IS.

As per IS 802-1995, weak suspension towers must be strengthened by strengthening the hip bracings. Where bracing strengthening is not possible due to the unavailability of shutdowns, interposing towers are to be installed. Also, interposing poles are to be placed in long-span lengths.
Poles with precast foundations can be used to restore lines quickly. LT bare conductors are to be replaced by AB cables during erection. One IS is for pole-testing, and BIS may publish cross-arm testing.
Due to the vibration of the tower, the nuts and bolts loosen over time. They are to be checked and tightened at least once every five years.

SCADA systems are to be extended to all 33/11kV substations. Smart grid in urban areas (municipalities and corporations) is to be initiated. GIS mapping of all assets to be done.

10.3 Technology and Innovation

In selected areas, we will adopt several new technologies, including H-type poles, spun poles, RLP poles, underground cabling system, ring main units (RMU), compact secondary substation (CSS), gas-insulated substation (GIS) and fault passage indicators (FPI).

We also plan to implement Smart Grid technologies in urban settings like municipalities and corporations, along with the installation of smart meters. Additionally, we will conduct GIS mapping of all electrical assets across our utilities.

To enhance efficiency, remote technology for cost-effective inspections of distribution poles in high-risk areas, substations and T&D lines will be used. Advanced technologies such as micro-grids, renewable energy sources, mobile substations, mobile generators, advanced distribution management systems, autonomous drones and real-time data analysis will be leveraged.

In times of disruption, critical assets and equipment using smart, automated switchgear to reroute power need to be isolated, thereby improving grid resilience.

Based on the detailed analysis/examination of this study (presented in different chapters in this report), recommendations are presented as given in Table 10.1 and 10.2

Table 10.1: Recommendations on Technology and Innovation

Activity	Recommendations on Technology and Innovation
Technology & Innovation	H-type poles, Spun poles, underground cabling system, ring main units (RMU), compact secondary substation (CSS), gas-insulated substation (GIS), fault passage indicators (FPI)
	SCADA systems are to be extended to all 33/11kV substations.
	Smart grid in urban areas (municipalities and corporations) and smart meter installation to be initiated.
	GIS mapping of all electrical assets across the utilities.
	Solar systems with sufficient storage capacity are to be encouraged. Rooftop PV cells need to be installed in hospitals, water supply systems, telecommunication towers, collectorate offices, etc. so that in case of non-availability of power supply from the grid, emergency power supply can be availed from the solar system. The PV cell supporting structures should be strengthened to withstand high wind speeds. They are designed to be modular and easily dismountable when cyclone warnings come.

Activity	Recommendations on Technology and Innovation
Technology & Innovation	Un-manned aerial vehicles (UAV)/Drones can be engaged for damage assessment immediately after a cyclone, monitoring the vegetation growth on both sides of the line. Even the line restoration works can be monitored with a UAV.
	Using remote technology to accelerate and promote cost-effective inspections of distribution poles in high-risk areas, substations and T&D lines.
	Using technologies such as micro grids, renewables, mobile sub-stations, Mobile Generators, advanced distribution management systems, autonomous drone usage and real-time analysis.
Risk Assessment	Isolating critical assets and equipment during disruption events (e.g., using smart automated switchgear) to reroute power and improve grid resilience.
Restoration, Recovery and Reconstruction	During restoration, if the damaged poles are replaced by the same type of poles, this may lead to further failure during cyclones. Hence, restorations are to be made as per the new design for 260 km/h i.e., the damaged Joist pole/PSC pole is to be replaced by H-Pole in 33kV and 11kV lines and by Spun Pole/H porcelain LT Lines as per the requirement.

Table 10.2: Recommendations on Codes, Standards, Design and Regulations

Activity	Recommendations on Codes, Standards, Design and Regulations	
Design	In sag tension calculation, one additional condition, full wind with local minimum temperature at the time of cyclone, is to be introduced. For example, in Odisha it will be 15C at full wind if the cyclone strikes during the last week of October or in the month of November.	Odisha Power Infrastructure Study
	Originally as per IE Rules 1956, this responsibility was with the State Government. However, the CEA Safety and Electricity Supply Regulation 2010 has specified that the temperature and pressures shall be as per the relevant Indian Standard. As per the IS, it is at 32C (everyday temperature) and full wind. It should be the average daily minimum temperature as specified in IEC 60826:2017 or as per the local site condition.	

Activity	Recommendations on Codes, Standards, Design and Regulations	
Design	Wind maps in IS 802 Part-1/Sec-1 and IS 875 have six wind zones. However, since 1985, IS 5613 Part-1/Section-1 still continues with the old concept of three pressure zones. This map is to be revised with wind speed zones as mentioned in the study. The ultimate load concept needs to be incorporated in this IS in line with IS 802 part-1/sec-1.	Odisha Power Infrastructure Study
	In the distribution system for load calculations, the same wind pressure is considered on both poles and conductors. A two-third diameter is considered in the case of circular sections.	Odisha Power Infrastructure Study
	Whereas in the case of transmission systems the wind pressures considered on tower structures and conductors are different. Furthermore, instead of two-third diameter in the case of circular sections, full diameter is considered as per IS 802. Uniformity is required in both cases, by revising IS 5613.	
	IS 802-2015 has suggested circular section members, whose drag co-efficient are less. These sections are to be adopted for new towers.	Odisha Power Infrastructure Study
	The design wind speed is 260 km/h, which has been considered in the study report taking k4 a factor of 1.3 and Zone-6 instead of Zone-5 as per the maps in IS.	Odisha Power Infrastructure Study
	802 and IS 875. (198 x 1.3 = 257.4 km rounded up to 260 km/h). This is to be adopted till the wind map in IS 802 and IS 5613 are revised.	
	The k4 factor (1.3) as stipulated in IS 15498:2004 (Guidelines for improving the cyclonic resistance of low-rise houses and other buildings/structures), IS 875 Part 3 must be considered. IS 802 (Part1 Section 1) for transmission lines does not have this factor. Hence, the k4 factor may be incorporated in IS 802.	CEA Task Force (March 2001) and DM plan of GOI (Prepared by plan of GOI
	The drag coefficient factor on tower members is to be increased in line with IEC. 60826:2017.	CEA Task Force (March 2001)
	Wind maps in IS 802 Part 1/Section 1 and IS 875 Part 3 are to be modified since these were prepared with the limited wind data up to 1982 and the climate change effects were not considered. The wind speeds as per the maps in CI I-I Risk Identification and Estimation are to be referred for modification of wind maps in IS.	CEA Task Force repor (March 2021)

Activity	Recommendations on Codes, Standards, Design and Regulations	
Design	As per CEA (Measures Relating to Safety and Electric Supply) Regulation 2010, the final unloaded tension at 320 C without external load is to be 25 percent. For distribution lines this can be changed to 15% in order to decrease the tension in the conductors at high wind speeds.	Odisha Power Infrastructure Study
	Existing Joist poles and rectangular cross-section PSC poles are not suitable in cyclone-prone areas since they are weak in the longitudinal direction. 33kV/11kV lines shall have H-Type poles (joining two Channels front to front) in place of Joist Poles and PSC Poles. LT lines have an RCC Spun pole/H-type pole.	Odisha Power Infrastructure Study
	H-type poles with E 350 grade (490 MPa) will be used.	Odisha Power Infrastructure Study
	IS 4091:1979 has stipulated that the depth of the embedment of the pole for the purpose of foundation should not be less than one-sixth of the total length of the pole above the ground. IS 785:1998 has specifies the minimum planting depth for poles of different sizes. For poor soil, the embedment depth/foundation size should be more based on the foundation design. But for all kinds of soils, the same minimum planting depth as specified in IS 1678 or Shown in REC drawings are maintained. It is suggested that the foundations be designed for different types of soils as classified in the CBIP Manual for transmission lines.	Odisha Power Infrastructure Study
	The span length for new lines is to be considered as suggested in the report. However, DISCOMs can calculate the span lengths per their requirement. Cross-arms strengths are to be verified with regard to tension developed in higher-size conductors at 260kM/h wind speed.	Odisha Power Infrastructure Study
	All the steel structures in coastal areas are to be galvanized with a higher thickness than the present practice.	Odisha Power Infrastructure Study
	Use of high-temperature low sag (HTLS) conductors in overloaded lines.	Odisha Power Infrastructure Study
	ACSR conductors instead of AAAC since the mechanical strength of the ACSR conductor is more than the strength of the AAAC conductor.	Odisha Power Infrastructure Study

Activity	Recommendations on Codes, Standards, Design and Regulations	
Design	At present, FRP poles are used for streetlights. Some specially designed FRP poles can be used in urban areas on a trial basis.	Odisha Power Infrastructure Study
RoW	Right-of-way provisions have been specified for 33kV and above voltage levels in IS 5613 and also in the Indian Electricity Act Section-68. However, the same has not been specified for 11kV and LT Lines. All the HT (33 and 11kV) and LT lines were damaged due to the falling of tree on it. Hence, RoW provisions for 11kV and LT lines are to be specified in the IS and Electricity Act.	Odisha Power Infrastructure Study
Installation	In the sea belt, soil conditions are usually not good for an open-cast foundation. Towers are to be provided with pile foundations.	Odisha Power Infrastructure Study
	Double-pole structures and guy supports are to be provided at the angle points and dead ends as per the REC standards. Where there are space constraints, struts are to be provided.	Odisha Power Infrastructure Study
	Steel poles are to be with concrete foundations and muffing.	Odisha Power Infrastructure Study
	Paragraph 3.3 of IS 785:1998 (Reaffirmed in 2014) states that the transverse direction is the direction of the line bisecting the angle between the conductor and the pole. Hence, where there is a deviation, the angle is to be bisected, and the pole is to be installed along the bisected line.	Odisha Power Infrastructure Study
	Earthings are to be provided as per the guidelines and relevant IS.	Odisha Power Infrastructure Study
	Proper compression/proper torque is to be applied when conductors are crimped or clamped.	Odisha Power Infrastructure Study
	In coastal areas due to salinity, polymer insulators are to be used. The existing porcelain insulators are to be replaced by polymer insulators.	Odisha Power Infrastructure Study
	In flood-/cyclone-prone areas the outdoor sub-stations are to be shifted to Indoor. Where the outdoor equipment foundation cannot be raised considering the DFL as per the flood zonation map given in CII.1 report and the existing PSC/Joist pole to be replaced by H-type poles in cyclone-prone areas	Odisha Power Infrastructure Study

Activity	Recommendations on Codes, Standards, Design and Regulations	
Installation	DTR below 100kVA should be installed on the H-type Pole and 100kVA and above are to be installed on the RCC plinth.	Odisha Power Infrastructure Study
	Weak suspension towers as per IS 802-1995 are to be strengthened by strengthening the hip bracings. Where bracing strengthening is not possible due to the unavailability of shut-downs, interposing towers are to be installed. Also, interposing poles are to be placed at long spans.	Disaster management plan of GOI (Prepared by CEA-Jan 2001) for long span lengths
	For retrofitting of the existing distribution lines interposing poles are to be installed as proposed in annexure.	Odisha Power Infrastructure Study
	Poles with precast foundation to quick restore lines quickly.	CEA Task Force report (March 2021)
	Installation LT bare conductors are to be replaced by AB Cables during erection.	CEA Task Force report (March 2021)
	Sag tension chart/sag table to be referred to during stringing.	Odisha Power Infrastructure Study
Testing	One IS for pole testing and cross-arm testing may be published by BIS.	Suggested by KEC in CEA Task Force meeting
O&M	For vegetation management, a district-level committee will be formed with the District Magistrate, Forest Department, Horticulture Department and the Transmission/Distribution Utility representatives. The committee will review the hindrances caused by any person(s) for tree cutting and suggest remedial actions to the district magistrate.	Odisha Power Infrastructure Study
	A third-party audit of vegetation management is to be done by the state government. The expenditure for the state government may bear such audit.	Odisha Power Infrastructure Study
	Due to the vibration of tower, the nuts and bolts get loosened in due course of time. They are to be checked and tightened at least once every five years.	CEA Task Force report (March 2021)

Activity	Recommendations on Codes, Standards, Design and Regulations	
O&M	Old conductors, old hardware fittings and Insulators that are more than 25 years old are to be tested and replaced suitably in the coastal belt.	Odisha Powe Infrastructure Study
	Epoxy paints to be applied on outdoor MS structures to avoid rusting.	Odisha Powe Infrastructure Study
Restoration	During restoration the damaged poles are replaced by the same type of poles which leads to further failure during cyclones. Hence restorations are to be made as per the new design for 260 km/h. For example, the damaged joist pole/PSC pole is to be replaced by H-Pole in 33kV and 11kV lines and by Spun Pole/H porcelain LT Lines as per the requirement.	Odisha Powe Infrastructure Study
New Technology	Underground cabling system, ring main units (RMU), compact secondary substation (CSS), gas-insulated substation (GIS), fault passage indicators (FPI) in urban area (statutory towns) are to be adopted in selected urban areas.	Odisha Powe Infrastructure Study
	SCADA systems are to be extended to all 33/11kV substations.	CEA Task Force report (March 2021)
	A smart grid in urban area (municipalities and corporations) to be initiated.	CEA Task Force report (March 2021).
	GIS mapping of all assets to be done.	CEA Task Force report (March 2021).
	Solar systems with sufficient storage capacity are to be encouraged. Rooftop PV cells need to be installed in hospitals, water supply systems, telecommunication towers, collectorate offices etc. so that in case the grid is not available, an emergency power supply can be obtained from the solar system. The PV cell supporting structures should be strengthened to withstand high wind speeds. They are to be dismantled when the cyclone warning comes.	Odisha Powe Infrastructure Study
	Unmanned aerial vehicle (UAV)/drones can be engaged on a trial basis for monitoring the vegetation growth on both sides of the line. Even the line restoration works can be monitored with UAV.	Odisha Powe Infrastructure Study

11 Conclusion and Way Forward

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The narrative of innovation in the power sector continues beyond there. Integrating advanced metering infrastructure allows utilities to gather real-time data on distribution network conditions. Smart meters play a crucial role, providing insights even during power outages by sending 'last gasp' indications before losing communication ability. This, coupled with phasor measurement units, power quality analyzers and digital protection relays, creates a comprehensive network that improves the understanding of a power system's condition and behaviour.

The extension of communication networks and the integration of supervisory control and data acquisition (SCADA) systems further enhance visibility and control. Due to increased situational awareness, utilities can now personalize messages to individual customers. The ability to reduce the impact of major disruptions and speed up restoration efforts has become a reality, marking a new era in the power sector where technology and innovation work hand in hand to ensure a resilient and efficient grid.

Disaster events have long posed significant challenges to our state's economic growth for centuries. Among the various sectors affected, the power sector plays a significant contributor to the state's GDP, bearing substantial losses in the face of frequent disasters. Over the past two decades, cyclones alone have caused estimated losses of 25,000 crores, considerably impacting Odisha's economy.

To mitigate future losses, fortifying power components in the coastal zone is imperative. This entails an investment in redesigning components according to modified standards and codes. The proposed investment in this report, totalling 28,000 crores, could impose a substantial financial burden on consumers if incorporated into the tariff. Therefore, it is crucial to explore funding mechanisms, such as grants or alternative sources, as advised by the Hon'ble Odisha Electricity Regulatory Commission (OERC) during discussions.

To manage this investment effectively, a phased approach prioritizing key areas is recommended for utilities. However, before finalizing any investment plan, utilities should thoroughly review proposals at the micro level. Component III, Task-5 of this study will investigate the funding mechanism and conduct a comprehensive cost-benefit analysis.

Annexure 1: Tables

Table A1.1: Bureau of India Standards

S. No	Indian Standards/Codes	Year of Publish	Code Description
1.	IS 15498	2004 (reaffirmed in 2015)	Guidelines for Improving the Cyclonic Resistance of Low-rise House and Other Building/Structures
2.	IS 5613 (Part 1/Sec 1)	1985 (reaffirmed 2012)	Code of Practice for Design, Installation and Maintenance of Overhead Power Lines up to and including 11kV – Section 1 Design
3.	IS 5613 (Part 1/Sec 2)	1985 (reaffirmed 2012)	Code of Practice for Design, Installation and Maintenance of Overhead Power Lines up to and including 11kV – Section 2 Installation and Maintenance
4.	IS 5613 (Part 2/Sec 1)	1985 (reaffirmed 2018)	Code of Practice for Design, Installation and Maintenance of Overhead Power Lines above 11kV and up to and including 220kV – Section 1 Design
5.	IS 5613 (Part 2/Sec 2)	1985 (reaffirmed 2018)	Code of Practice for Design, Installation and Maintenance of Overhead Power Lines above 11kV and up to and including 220kV – Section 2 Installation and Maintenance
6.	IS 5613 (Part 3/Sec 1)	1985 (reaffirmed 2019)	Code of Practice for Design, Installation and Maintenance of Overhead Power Lines – 400kV – Section 1 Design
7.	IS 5613 (Part 2/Sec 2)	1985 (reaffirmed 2019)	Code of Practice for Design, Installation and Maintenance of Overhead Power Lines - 400kV – Section 2 Installation and Maintenance
8.	IS 802 Part 1/Sec 1	2015	Use of Structural Steel in Overhead Transmission Line Towers-Code of Practice – Materials and Loads
9.	IS 802 Part 1/Sec2	2016	Use of Structural Steel in Overhead Transmission Line Towers-Code of Practice – Design Strength
10.	IS 802- Part 2	1978 (reaffirmed 2017)	Use of Structural Steel in Overhead Transmission Line Towers-Code of Practice – Fabrication, Galvanizing, Inspection and Packing
11.	IS 802- Part 3	1978 (reaffirmed 2018)	Use of Structural Steel in Overhead Transmission Line Towers-Code of Practice – Testing

S. No	Indian Standards/Codes	Year of Publish	Code Description
12.	IS 875 (Part III)	2015	Wind loads on buildings and structures
13.	IS 4091	1985 (reaffirmed 2020)	Design and construction of foundation for transmission line tower and pole
14.	IS 808	2021	Hot Rolled Steel Beam, Column, Channel and Angle Sections – Dimensions and Properties
15.	IS 2713 (Part I to III)	1980 (reaffirmed 2017)	Tubular steel poles for overhead power lines
16.	IS 785	1998 (reaffirmed 2019)	Reinforced concrete Poles for overhead power and telecommunication lines
17.	IS 13158	1991 (reaffirmed 2017)	Pre-stressed concrete circular spun poles for overhead power, traction and telecommunication lines.
18.	IS 456	2000 (reaffirmed 2021)	Code of Practice for Plain and Reinforced Concrete.
19.	IS 398 (Part 1)	1996 (reaffirmed 2018)	Aluminium conductor for overhead transmission purposes – Aluminium stranded conductor
20.	IS 398 (Part 2)	1996 (reaffirmed 2018)	Aluminium conductor for overhead transmission purposes – Aluminium conductors, galvanized steel reinforced
21.	IS 398 (Part 3)	1976 (reaffirmed 2019)	Aluminium conductor for overhead transmission purposes – Aluminium conductors, aluminized steel reinforced
22.	IS 398 (Part 4)	1994 (reaffirmed 2014)	Aluminium conductor for overhead transmission purposes – Aluminium alloy stranded conductor (aluminium magnesium silicon type)
23.	IS 398 (Part 5)	1992 (reaffirmed 2018)	Aluminium conductor for overhead transmission purposes – Aluminium conductors, galvanized steel reinforced for extra high voltage (400kV and above)
24.	IS 398 (Part 6)	2021	Aluminium conductor for overhead transmission purposes – High conductivity Aluminium Alloy Stranded Conductors

S. No	Indian Standards/Codes	Year of Publish	Code Description
25.	IS 731	1971 (reaffirmed 2016)	Specification of porcelain insulators for overhead power lines above 1000 V
26.	IS 1445	1977 (reaffirmed 2019	Specification for porcelain insulators for overhead power lines with a nominal voltage up to and including 1000 V
27.	IS 2486 (Part 1)	1993 (Reaffirmed 2018)	Metal fittings of insulators for overhead power lines with nominal voltage greater than1000 V – General requirements and tests
28.	IS 2486 (Part 2)	1989 (Reaffirmed 2019)	Metal fittings of insulators for overhead power lines with nominal voltage greater than1000 V – Dimensional requirements
29.	IS 2486 (Part 3)	1974 (Reaffirmed 2021)	Metal fittings of insulators for overhead power lines with nominal voltage greater than1000 V – Locking devices
30.	IS 2486 (Part 4)	1981 9reaffirmed 2021)	Metal fittings of insulators for overhead power lines with nominal voltage greater than1000 V – Tests for locking devices
31.	IS 7935	1975 (Reaffirmed 2021)	Insulator fittings for overhead power lines with a nominal voltage up to and including 1000 V
32.	IS:5300	1969 (reaffirmed 2019)	Porcelain guy strain insulator
33.	IS 14255	1995 (Reaffirmed 2015)	Aerial Bunched cables for working voltage up to and including 1100 V

Table A1.2 REC Specifications and Standards

S. No	Name of the Specification	Specification No.
1.	Hard Drawn Stranded Aluminium and Steel Cored Aluminium Conductors for Overhead Power Lines	1/1971(R-1993)
2.	11kV Porcelain Insulators and Fittings	3/1971(R-1993)
3.	Porcelain Insulators and Insulator Fittings for 415/240V Overhead Power Lines	4/1972(R-1979)
4.	Porcelain Insulators and Insulator Fittings for 33kV Overhead Power Lines	13/1979
5.	Pre-stressed Cement Concrete poles (FOS 2.5) for 11kV and LT Lines	15/1979
6.	Guy strain insulators	21/1981
7.	Pre-stressed Concrete Poles for 33kV Lines	24/1983(R-1987)
8.	Aerial Bunched Cables for LT Lines	32/1984
9.	Aluminium Alloy Conductors for Overhead Power Lines	33/1984(R-1993)
10.	Fibreglass Cross Arms for 11kV Lines	40/1985(R-1997)
11.	Rectangular Hollow Steel Poles	41/1985
12.	Fibre Glass Cross Arms for 33kV Lines	42/1987(R-1997)
13.	GI Wires	45/1986
14.	GI Stay Wires	46/1986
15.	Pre-stressed Concrete Spun Poles	47/1987
16.	Epoxy Based Protective Paint	51/1987
17.	High Tensile Steel Wires for PCC Poles	62/1993
18.	Aerial Bunched Cables for 11kV Lines	64/1993

Table A1.3: REC Construction Standards

S. No	Name of the Standard	Description
1.	Construction Standard A-2	11kV Lines – Conductor Formation and Clearances without Earth Line
2.	Construction Standard A-4	11kV Lines – Supports without Earth Wire
3.	Construction Standard A-6	11kV Lines – 'V' Cross Arm (M.S. Channel)
4.	Construction Standard A-7	11kV Lines – Pole Top Bracket
5.	Construction Standard A-8	11kV Lines – Permissible Spans (Tables)
6.	Construction Standard A-16	11kV Lines – Conductor Formation and Clearance of 11kV Three-phase Line
7.	Construction Standard A-21	11kV Lines – Arrangement at Tension Locations
8.	Construction Standard A-23	11kV Lines – Arrangement of Guys for 0° to 10° deviations Angle.
9.	Construction Standard A-24	11kV Lines – Arrangement of Guys for 10° to 60°(Single Pole)
10.	Construction Standard A-25	11kV Lines – Arrangement of Guys for 10° to 60° (D.P)
11.	Construction Standard A-26	11kV Lines – Arrangement of Guys for 60° to 90°(-Four Pole)
12.	Construction Standard A-27	11kV Lines – Arrangement of Guys for Dead End Locations (D.P) (Double Pole Support)
13.	Construction Standard A-34	11kV Lines – Permissible Spans for 11kV Lines with AAAC
14.	Construction Standard B-8	Max. Permissible Span for Three-phase LT Line
15.	Construction Standard B-10	415 V – Arrangement for Conductor at Angle Loc
16.	Construction Standard B-11	Max. Permissible Span for LT Line
17.	Construction Standard B-20	LT Line Arrangement of Guys for 0°to 10° Angle Loc
18.	Construction Standard B-21	LT Line Arrangement of Guys for 10° to 60° Angle Loc
19.	Construction Standard B-22	LT Line Arrangement of Guys for 10° to 60° Angle Loc
20.	Construction Standard B-23	LT Line Arrangement of Guys for 60° to 90° Angle Loc
21.	Construction Standard B-24	LT Line Arrangement of Guys for dead End Loc

S. No	Name of the Standard	Description
22.	Construction Standard A-25	3Φ 5 W Line – Arrangement of Guys for 0° to 10°
23.	Construction Standard B-26	3Φ 5 W Line – Arrangement of Guys for 10° to 30°
24.	Construction Standard B-27	3Φ 5 W Line – Arrangement of Guys for 30° to 60°
25.	Construction Standard B-28	3Φ 5 W Line – Arrangement of Guys for 60° to 90°
26.	Construction Standard B-29	3Φ 5 W Line – Arrangement of Guys for Dead End Loc
27.	Construction Standard M-7	33kV Lines – Arrangement of Conductors at Angle Location 0° – 10° deviation
28.	Construction Standard M-8	33kV Lines – Arrangement at 10° – 60° deviation
29.	Construction Standard M-9	33kV Lines – Arrangement at 60° – 90° deviation

Table A1.4: International Standards and Codes

S. No	Code	Year	Description
1.	IEC 60826	2017	Over Head Transmission Line Design Criteria
2.	IEC 60652	2002	Loading tests on overhead line structures
3.	IEC 61284	1997	Overhead lines –Requirements and tests for fittings
4.	IEC 815	1986	Guide for selection of insulators in respect of polluted conditions
5.	IEC 60815-1	2008	Selection and dimensioning of High Voltage insulators intended for use in polluted conditions – Definitions, information and general principles
6.	IEC 60815-2	2008	Selection and dimensioning of High Voltage insulators intended for use in polluted conditions – Ceramic and glass insulators for a. c. systems
7.	IEC 60120	1984	Dimensions of ball and socket couplings of string insulator units
8.	IEC:60815-3	2008	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Polymer insulators for AC systems.
9.	IEC 61109	2008	Composite suspension and tension insulators for AC systems with a nominal voltage greater than 1000 V – Definitions, test methods and acceptance criteria
10.	IEC 60433	1998	Insulators for overhead lines above 1000V –ceramic insulators – Characteristics of insulators for long rod type
11.	IEC 60383	-	Insulators for overhead lines with a nominal voltage above 1000 V- part 2: insulator strings and insulator sets for AC systems definitions, test methods and acceptance criteria
12.	ANSIC29-2	-	American national standard for insulators wet process porcelain and toughened glass suspension type.
13.	IEC 60305	-	Characteristics of string insulators
14.	ASCI	-	Guidelines for electrical transmission line structural loading

Table A1.5 : 132kV UG Cabling Under SCRIPS Scheme (In Operation)

S. No	From GSS	To GSS
1.	Chandaka 220/132/33kV GIS IEC 60652	Unit-8 132/33kV GIS
2.	Chandaka 220/132/33kV GIS	Mancheswar-B 132/33kV GIS
3.	Mancheswar-B 132/33kV GIS	Mancheswar-A 132/33kV AIS

Table A1.6: 132kV UG Cabling Under SCRIPS Scheme (Under Construction)

S. No	From GSS	To GSS
1.	Mancheswar-A 132/33kV AIS	Nayapali-132/33kV AIS
2.	Unit-8 132/33kV GIS	Nayapali 132/33kV GIS
3.	Unit-8 132/33kV GIS	Satyanagar-132/33kV GIS
4.	Badagada 132/33kV GIS	Satyanagar-132/33kV GIS
5.	Mancheswar-B 132/33kV GIS	Satyanagar 132/33kV GIS
6.	Balianata 220/132kV GIS	Mancheswar-B 132/33kV GIS

Table A1.7: 132kV UG Cabling Under DRPS Phase-2 (Under Proposal)

S. No	From GSS	To GSS
1.	Mendhasal 400/220/132kV AIS	Chandaka-B 220/132kV
2.	Arugul 132/33kV AIS	Ranasinghpur 132/33kV AIS
3.	Narendrapur 220/132/33kV AIS	Berhampur 132/33kV
4.	Puri 132/33kV AIS	Samagara 220/132kV GIS
5.	Chandaka-B 220/132kV GIS	Brajabiharipur 132/33kV

Table A1.8: 132kV OH Lines Converted to HTLS Conductors

S. No	From GSS	To GSS	Circuits
1.	Chandaka-A 220/132kV AIS	Mancheswar-A 132/33kV AIS	Double
2.	Chandaka-A 220/132kV AIS	Ranasinghpur 132/33kV AIS	Single

Table A1.9: REC Construction Standard

Type of Line with Deviation	Stipulation in the Standard
11kV line 0 to 10° deviation	Single pole with single guy
11kV line with vertical conductor configuration10° to 60° deviation	Single pole with single guy
11kV line 30° to 60° deviation	DP with two guys
11kV line 60° to 90° deviation	Four poles with four guys
11kV dead end	DP with two guys
LT line 0° to 10° deviation	Single pole with single guy
LT line 10° to 30° deviation	Single pole with single guy
LT line 30° to 60° deviation	Single pole with single guy
LT line 60° to 90° deviation	Single pole with single guy
LT dead end	Single pole with single guy
33kV line 0° to 10° deviation	Single pole with two guys
33kV line 10° to 60° deviation	DP with four guys
33kV line 60° to 90° deviation	Four poles with four guys

Table A1.10: Steel Poles (Section Modulus) -IS 808

S. No	Steel Section Size	Section Modulus for Transverse Force along the Direction of the Line (cm^3)	Section Modulus for Longitudinal Force Along the Transverse Direction Axis (cm^3)	% of Section Modulus for Transverse Force
1.	Steel joist 150 X 150 mm (34.6 kg/m)	218	63.2	28.99%
2.	Steel Joist 152 X 152mm (37.1 kg/m) (REC specified standards)	259	91.9	35.48%
3.	Steel WPB 160 X 160 (30.44 kg)	220.1	76.9	35%
4.	Steel Joist 116 X 100 mm (23 kg/m) (This size is not available in the IS)	111	28.7	25.86%
5.	Steel Joist 125 X 70mm (13.3 kg/m))	71.2	11	15.45%
6.	Steel Joist 175 X 85mm (19.6 kg/m) (REC specified in SBD)	144	18	12.5%

Table A1.11: Conductor Tension at 260 km/h Wind Speed for 33kV Line

Type of Conductor/Size	% Wind Pressure	Temp.	Reference	Tension at 260 km/h in kgf (If Erection Tension Is Considered 25%)	Tension at 260 km/h in kgf (If Erection Tension is Considered 15%)	Ground Clearance at Maximum Temperature (95° C and No Wind) in 13 m pole (Req. Ground Clearance 6.1 m Across a Street)		UTS in kgf
						At 25%	At 15%	
AAAC80	100	32	As per IS 802 & 5613	1189	1097	8.723	8.445	2386.3
	100	5	As per 5613	1319	1209			
	100	15	As per Local condition	1268	1164			
AAAC100	100	32	As per IS 802 & 5613	1387	1272	8.727	8.446	2983.0
	100	5	As per 5613	1553	1412			
	100	15	As per Local condition	1488	1357			
AAAC148	100	32	As per IS 802 & 5613	1830	1655	8.740	8.475	4434.3
	100	5	As per 5613	2076	1859			
	100	15	As per Local condition	1979	1778			
AAAC232	100	32	As per IS 802 & 5613	2766	2253	8.743	8.476	6879.7
	100	5	As per 5613	2924	2572			
	100	15	As per Local condition	2766	2444			

Table A1.12: Substation Power Supply Redundancy

GSS	Voltage Level (kV)	Supply Source	No of Circuits	No of Tower	Alternate Source	Risk
Bhogarai	132/33	Dual	Two	Single	Yes	Yes
Jaleswar	132/33	Dual	Two	Single	Yes	Yes
Balesore	220/132	Dual	Two	Two	Yes	No
Balesore	132/33	Dual	Four	Two	Yes	No
Chandipur	132/33	Dual	Two	Single	Yes	Yes
Soro	132/33	Dual	Four	Two	Yes	No
Dhamra	132/33	Single	Single	Single	No	Yes
Bhadrak	220/132	Dual	Four	Two	Yes	No
Jajpur Town	132/33	Dual	Two	Single	Yes	Yes
Paradeep	220/132	Dual	Two	Single	Yes	Yes
Paradeep	132/33	Dual	Two	Two	Yes	No
Tirtol	132/33	Dual	Two	Two	Yes	No
Jagatsinghpur	132/33	Dual	Two	Two	Yes	No
Cuttack	220/132	Single	Two	Single	No	Yes
Cuttack	132/33	Dual	Two	Two	Yes	No
Konark	132/33	Single	Single	Single	No	Yes
Nimapada	132/33	Dual	Two	Two	Yes	No
Puri	132/33	Dual	Two	Two	Yes	No
Samagara	220/33	Single	Two	Single	No	Yes
Samuka	132/33	Dual	Two	Two	Yes	No
Unit-8	132/33	Single	Single	Cable	No	No
Chandaka AIS	220/132	Single	Four	Two	No	No
Chandaka GIS	220/132	Single	Four	Two	No	No
Bidanasi	220/132	Single	Two	Single	No	Yes
Ganjam	132/33	Single	Single	Single	No	Yes
Chatrapur	132/33	Dual	Four	Two	Yes	No
Narendrapur	220/33	Dual	Four	Two	Yes	No
Berhampur	132/33	Dual	Four	Two	Yes	No
Chikiti	132/33	Single	Two	Single	No	Yes
Chandpur	132/33	Dual	Two	Two	Yes	No
Balugaon	132/33	Dual	Four	Two	Yes	No

Table A1.13: Section Modulus for Joist and H-Poles

Pole Type	Unit Mass	Section Modulus for Transverse Force Along the Direction of the Line (cm^3)	Section Modulus for Longitudinal Force Along the Transverse Direction Axis, (cm^3)
Steel Joist 150 X 150 mm in the existing 33kV lines	34.6 kg/m	218	63.2
2 X 150 X 75 mm H Pole proposed for 33kV lines	36.96 kg/m	479	210

Table A1.14: Section Modulus for H-type Pole

S. No	H-type Pole size	Section Modulus for Transverse Force along the Direction of the Line (cm^3)	Section Modulus for Longitudinal Force Along the Transverse Direction Axis (cm^3)
1.	2 X 200 X 75 mm H Pole (49.06 kg/m)	641	366, which is 57% of 641
2.	2 X 175 X 75 mm H Pole (43.12 kg/m)	561	283, which is 50% of 561
3.	2 X 150 X 75 mm H Pole (36.96 kg/m)	479	210, which is 43.8% of 479
4.	2 125 X 65 mm H Pole (28.82 kg/m)	323	136, which is 42% of 323
5.	2 X 100 X 50 mm H Pole (21.03 kg/m)	180	77, which is 42.6% of 180
6.	2 X 75 X 40 mm H Pole (15.71 kg/m)	105	42, which is 40% of 105

Table A1.15: Modulus Calculations of H Poles

S. No	Description	Unit)	2X200X75 H-Type Pole (49.06 kg)	2X175X75 H-Type Pole (43.02 kg)	2X150X75 H-Type Pole (36.96 kg)	2X125X65 H-Type Pole (28.02 kg)	2X100X50 H-Type Pole (21.03 kg)	2X75X40 H-Type Pole (15.71 kg)
1.	Channel depth	mm	200	175	150	125	100	75
2.	Channel breadth	mm	75	75	75	65	50	40
3.	Wt. of one channel	kg	22.30	19.6	16.8	13.1	9.56	7.14
4.	Wt. of two channels	kg	44.60	39.20	33.60	26.20	19.12	14.28
5.	Steel grade	N/mm2	250.00	250.00	250.00	250	250	250
6.	Total Wt. including batten (10 %)	kg	49.06	43.12	36.96	28.82	21.03	15.71
7.	Sectional area, A	cm2	28.50	24.9	21.3	16.7	12.2	9.1
8.	C.G, CYY	mm	22.00	21.9	22	19.5	15.4	13.2
9.	Space between two channels	mm	150.00	150	150	130	100	80
10.	S (2X Breadth + Space)	mm	300.00	300.00	300.00	260.00	200	160
11.	I xx (single)	cm4	1830.00	1240	788	425	192	78.5
12.	I xx (for 2 channels)	cm4	3660.00	2480.0	1576.0	850.00	384.00	157.0
13.	I yy bar	cm4	141.00	122	103	61.1	26.7	12.9
14.	Y bar	cm	12.80	12.81	12.80	11.05	8.46	6.68
15.	Y max	mm	150.00	150.00	150.00	130.00	100.00	80.0
16.	Y max, xx	mm	100.00	87.50	75.00	62.50	50.00	37.5
17.	I yy	cm4	9620.88	8415.9	7185.6	4200.42	1799.75	837.9
18.	Rx	cm	8.01	7.06	6.08	5.04	3.97	2.94
19.	Ry	cm	12.99	13.00	12.99	11.21	8.59	6.79
20.	Modulus, Zx	cm3	366.00	283.43	210.13	136.00	76.80	41.87
21.	Modulus, Zy	cm3	641.39	561.07	479.04	323.11	179.97	104.7

Table A1.16: Horizontal Tension on Conductors

Type of H-Pole	Steel Grade and Pole Height	Longitudinal Direction Withstand Capacity (in kgf)	Horizontal Tension on Conductors (in kgf)			
			80 mm²	100 mm²	148 mm²	232 mm²
2 X 150 X 75 mm, 36.96 kg,	E250,13 m	281.45	75.61	99.20	159.59	278.86
	E250,11 m	340.51	75.61	99.20	159.59	278.86
	E350,13 m	394.03	75.61	99.20	159.59	278.86
	E350,11 m	476.72	75.61	99.20	159.59	278.86

Table A1.17: Interposing H-Pole in Existing Joist Pole Line – 35 m Span Length (33kV)

Pole Height (in m)	Type of AAAC Conductor (mm²)	Capacity to Withstand Wind Speed in km/h with FoS for H-Pole		Capacity to Withstand Wind Speed in km/h with FoS for Joist Pole	
		As per IS 5613	As per IS 802	As per IS 5613	As per IS 802
13	80	284	259	192	174
	100	277	254	187	171
	148	263	243	177	162
	232	248	230	167	155
11	80	327	299	220	201
	100	319	292	215	196
	148	300	277	203	187
	232	282	263	190	176

Table A1.18: New H-Pole Line with 50 m Span Length (33kV)

Pole Height (in m)	Type of AAAC Conductor (mm²)	Capacity to Withstand Wind Speed in km/h with FoS	
		As per IS 5613	As per IS 802
13	80	309	284
	100	300	277
	148	282	263
	232	262	247
11	80	352	326
	100	341	316
	148	319	299
	232	296	279

Table A1.19: New H-Pole Line with 50 m Span Length (33kV)

Pole Height (in m)	Type of AAAC Conductor (mm²)	Capacity to Withstand Wind Speed in km/h with FoS	
		As per IS 5613	As per IS 802
14	80	296	270
	100	262	241
	148	246	228
	232	228	212

Table A1.20: Interposing H-Pole in Existing Joist Pole Line - 30 m Span Length (11kV)

Pole Height (in m)	Type of AAAC Conductor (mm^2)	Capacity to Withstand Wind Speed in km/h with FoS for H-Pole		Capacity to Withstand Wind Speed in km/h with FoS for Joist Pole	
		As per IS 5613	As per IS 802	As per IS 5613	As per IS 802
10	55	331	303	205	188
	80	316	291	194	180
	100	307	284	188	175
9	55	354	325	219	202
	80	337	311	207	193
	100	327	302	200	187

Table A1.21: New H-Pole Line with 50 m Span Length (11kV)

Pole Height (in m)	Type of AAAC Conductor (mm^2)	Capacity to Withstand Wind Speed in km/h with FoS	
		As per IS 5613	As per IS 802
10	55	341	318
	80	322	300
	100	310	291
9	55	363	339
	80	341	320
	100	329	310

Table A1.22: New H-Pole line with 50 m Span Length (11kV)

Pole Height (in m)	Type of AAAC Conductor (mm^2)	Capacity to Withstand Wind Speed in km/h with FoS	
		As per IS 5613	As per IS 802
13	55	327	297
	80	287	263
	100	277	256

Table A1.23: Spun Pole LT Line with 30 m Span

S. No.	Type of AB Cable	Capacity to Withstand Wind Speed in km/h with FoS
		As per IS 5613
1.	3 X 16 + 25 bare +1 X 16 mm²	283
2.	3 X 25 + 25 bare + 1 X 16 mm²	270
3.	3 X 35 + 25 bare +1 X 16 mm²	263
4.	3 X 50 + 35 bare +1 X 16 mm²	252

Table A1.24: Spun Pole LT Line with 40 m Span

S. No.	Type of AB Cable	Capacity to Withstand Wind Speed in km/h with FoS
		As per IS 5613
1.	3 X 16 + 25 bare +1 X 16 mm²	254
2.	3 X 25 + 25 bare + 1 X 16 mm²	250
3.	3 X 35 + 25 bare +1 X 16 mm²	243
4.	3 X 50 + 35 bare +1 X 16 mm²	231

Table A1.25: H-Poles LT Line with 40 m Span

S. No.	Conductor/ AB Cable Size (mm²)	Capacity to Withstand Wind Speed in km/h Considering the FoS	
		As per IS 5613	As per IS 802
1.	3 X 16 + 25 bare +1 X 16 mm²	369	363
2.	3 X 25 + 25 bare + 1 X 16 mm²	360	352
3.	3 X 35 + 25 bare +1 X 16 mm²	350	331
4.	3 X 50 + 35 bare +1 X 16 mm²	331	312

Table A1.26: Prioritization of 33kV Lines (in km)

DISCOM	Priority 1			Priority 2			Priority 3			Total Length
	0-20	20-60	>60	0-20	20-60	>60	0-20	20-60	>60	
TPCODL	539	0	0	432	116	0	1	316	169	1574
TPNODL	707	0	0	67	508	0	0	201	113	1596
TPSODL	442	0	0	48	656	0	38	110	133	1427

Table A1.27: Prioritization of 11kV Lines (in km)

DISCOM	Priority 1			Priority 2			Priority 3			Total Length
	0-20	20-60	>60	0-20	20-60	>60	0-20	20-60	>60	
TPCODL	6319	0	0	7279	1944	0	0	2718	0	18260
TPNODL	4627	0	0	6624	438	0	0	3830	0	15519
TPSODL	3134	0	0	0	6352	0	0	2828	2045	14359

Table A1.28: Prioritization of LT Lines (in km)

DISCOM	Priority 1			Priority 2			Priority 3			Total Length
	0-20	20-60	>60	0-20	20-60	>60	0-20	20-60	>60	
TPCODL	18958	0	0	21836	5832	0	0	8155	0	54781
TPNODL	13882	0	0	19872	1313	0	0	11489	0	46557
TPSODL	9403	0	0	0	19055	0	0	8484	6136	43078

Table A1.29: K Factors and Wind Pressure Calculations by Different Agencies

			Agency A for H pole		Agency B for Steel Tubular Pole		Agency C for spun pole			
		IS 875 Stipulations	For APDRP	Equiv. Zone 5 for Comparison	For DDUGJY	Equiv. Zone 5 for Comparison	Initial Calculation Zone 6	Equiv. Zone 5 for Comparison	Revised Calculation Zone 6	Equiv. Zone 5 for Comparison
Wind speed (km/h)			300.00	180.00	-	-	-		-	
Wind speed (m/s)	50	50	83.30	50.00	44.00	50.00	55.00	50.00	55.00	50
Division factor to convert 3 s gust speed to 10 min average speed	1.375	=	1.375		-	-	1.375	1.375	-	=
10 min average speed, VR	36.37		60.58	36.37	-	-	40.00	36.37	-	=
K1 (reliability/Risk Coeff)	1.0 (for 400kV and below)	1.0 for general bldg. with 50-year life	-	-	1.07 in place of 1.0		1.0	1.0	1.08	1.08
Terrain category factor k2 (for open field)	1.08 (for open field)	1.05 (open field 10 m height)	-	-	1.08		1.08	1.08	0.66 (Hourly average factor)	0.66 (Hourly average factor)
Topography factor (k3)	-	1.0 to 1.36 (1.0 for plane area)	-	-	1.0		-	-	1.0	1.0
Cyclonic factor, k4	-	1.3	-	-			-		1.3	1.3
Design wind speed, Vb	VR X k1 X k2= 39.27	Vb X k1 X k2 X k3 X k4 = 68.25	60.58	36.36	50.85	57.78	43.20	39.27	51.11	46.33
Design wind speed (in km/h)	141.372		218.09	130.91	183.6	208.0	1120	141.372	183.996	166.79
Wind pressure (0.6 X Vd2) in N/m2	925	2794.84	2202.09	793.39	1551.43	2003.12	1120	925	1567.55	1287.99
Wind pressure (kgf/m2)	94.34	285.04	224.57	80.91	158.23	204.3	114.2	114.2	159.87	131.36
	Gust factor, Drag coefficient. No factor of safety	Gust factor, Force coefficient. Also factor of safety			No gust factor. No drag coefficient. But with factor of safety					

Figure A1.1: T&D network in Puri

Figure A1.2: 33kV connectivity for Puri city

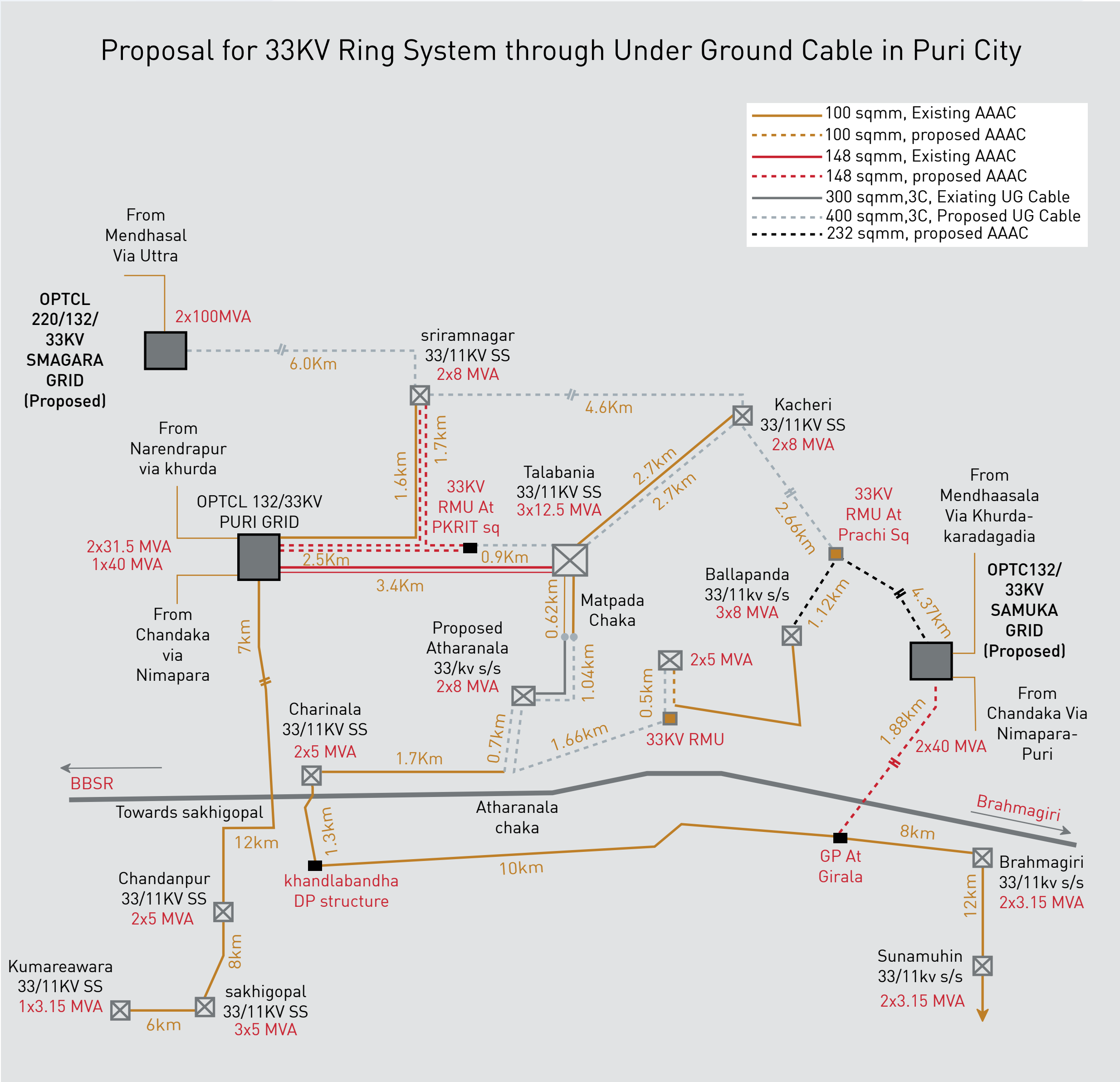
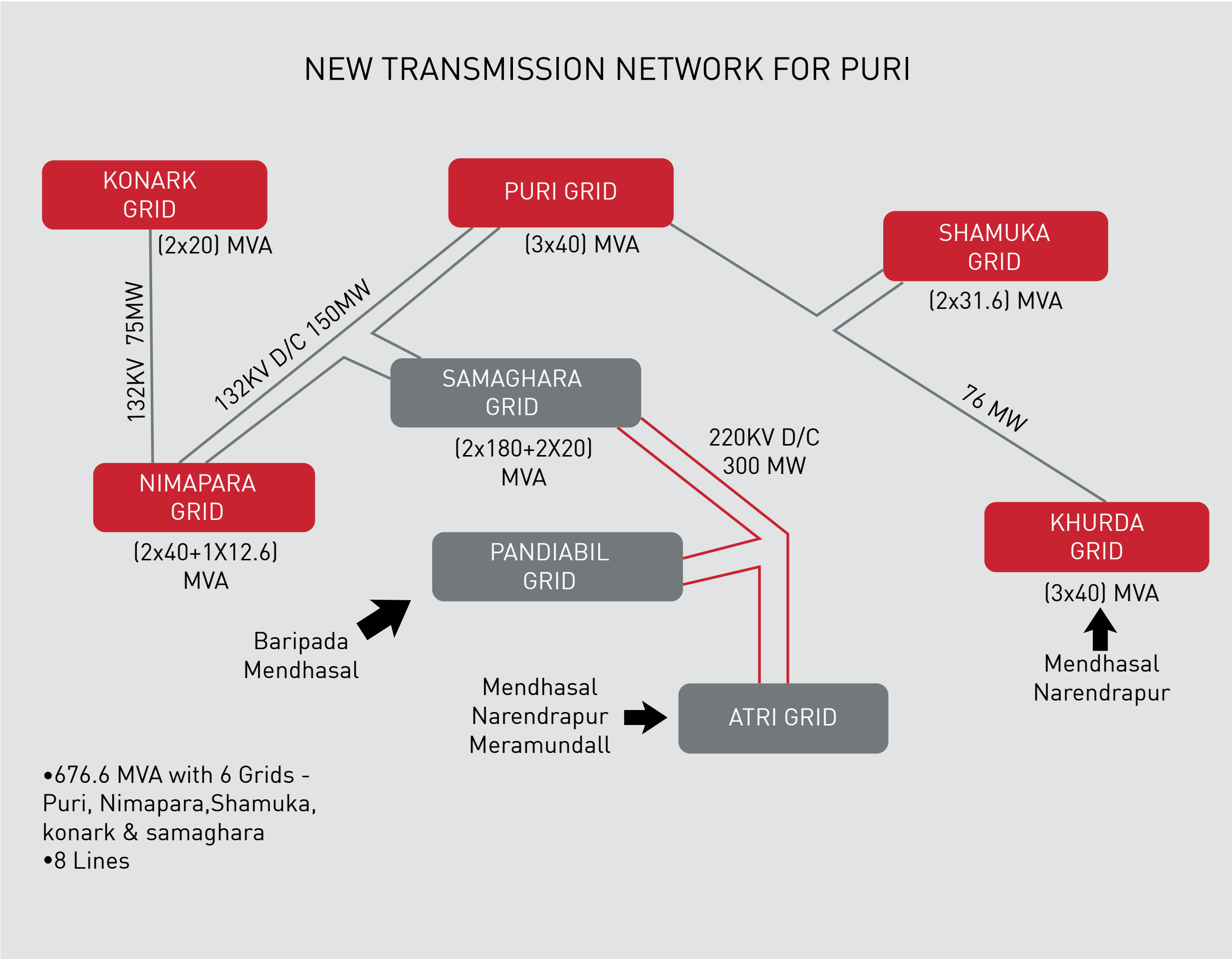


Figure A1.3: Transmission network



Annexure 2: Intensity and Weather in Association with Tropical Cyclones

Table A2.1: Intensity and Weather in Association with Tropical Cyclones

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
1990	Severe cyclonic storm with a core of Hurricane winds over the Bay of Bengal, 4-10 May	90 kt	System crossed the south Andhra Pradesh coast in India at about 1330 UTC of 9 May about 40 km southwest of Machilipatnam
1990	Severe cyclonic storm over the Bay of Bengal, 14-18 December	25 kt	System crossed Bangladesh coast near Cox Bazar as a depression in the midnight of 18 December
1991	Cyclonic storm over the southeast Bay of Bengal, 24-30 April	127 kt	Crossed Bangladesh coast during the midnight hours of 29-30 April 1near about the time of high tide
1991	Cyclonic storm over southeast Bay of Bengal, 31 May-02 June	45 kt	Crossed Bangladesh coast in the morning of 02 June
1991	Cyclonic storm over southeast the Bay of Bengal,11-15 November	35 kt	Cyclonic storm crossed Tamil Nadu coast in India between Nagapattinam (43347) and Cuddalore (43329) near Karaikal (43346) in the early hours of 15 November
1992	Cyclonic storm over the Bay of Bengal, 16-19 May	35 kt	The system crossed the Myanmar coast in the mid-day around 0600 UTC of 19 May
1992	Cyclonic storm over the Arabian Sea, 08-12 June	Weakened over sea	The system rapidly weakened and dissipated over the sea area off the south Yemen coast by the evening of 12 June
1992	Cyclonic storm over Arabian Sea, 01-03 October 1992	45 kt	The system crossed the Oman coast around 0200 UTC near Lat 19.7°N and Long 57.7°E on 3 October
1992	Cyclonic storm over the Bay of Bengal, 20-22 October	35 kt	The system crossed the Bangladesh coast in the early hours of 22 October
1992	Cyclonic storm over the Bay of Bengal, 03-06 November	Weakened over sea	The system rapidly weakened over the high seas by the mid-day of 7 November

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
1992	Severe cyclonic storm over south Bay of Bengal, 11-17 November		After crossing Sri Lanka, it emerged into the Gulf of Mannar, intensified into a severe cyclonic storm on 13 November afternoon and crossed south Tamil Nadu coast. Later it crossed Karnataka coast near Honavar on the afternoon of the 17 November and rapidly weakened
1992	Severe cyclonic storm with a core of Hurricane winds over the Bay of Bengal, 16-21 November	45kt	The hurricane rapidly weakened into a cyclone before crossing the Bangladesh Myanmar coast on the afternoon of 21 November
1993	Severe cyclonic storm with a core of Hurricane winds over Arabian sea, 12-15 November	Weakened over Sea	The system weakened into a well-marked low-pressure area over the northeast Arabian Sea off Gujrat-Sind coast by the morning of 16 November
1993	Cyclonic storm with a core of Hurricane winds over the Bay of Bengal, 01-04 December	90 kt	The system crossed Tamil Nadu coast near Karaikal between 0400 and 0500 UTC of 4 December and dissipated over south Karnataka by the morning of 5 December
1994	Cyclonic storm with a core of Hurricane winds over the Bay of Bengal, 29 April-02 May	115 kt	Crossed Bangladesh-Myanmar Coast near Technaf by 1700 UTC of 02 May
1994	Severe cyclonic storm over the Arabian Sea, 05-09 June	Weakened over sea	The system weakened into deep depression, then into depression and dissipated finally near the Oman coast by the evening of 9 June
1994	Severe cyclonic Storm over the Bay of Bengal, 29-31 October	60 kt	The system crossed the north Tamil Nadu coast near Madras between 0100 and 0200 UTC of 31 October
1994	Severe cyclonic storm with a core of Hurricane winds over the Bay of Bengal, 15-20 November	35 kt	System crossed the coast of north Somalia in the early morning of 20 November
1995	Cyclonic storm over the Arabian Sea, 12-17 October	Weakened over sea	Weakened into a well-marked low over the west-central Arabian Sea by the evening of 17/10/1995

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
1995	Severe cyclonic storm with a core of Hurricane winds over the Bay of Bengal, 07-10 November	77kt	The system crossed Andhra Pradesh Orissa coast between Kalingapatnam and Gopalpur around 0500UTC of 09 November as severe cyclonic storm and weakened into a well-marked low over Bihar plains and adjoining east U.P. by 1200UTC of 10 November
1995	Severe cyclonic storm with a core of Hurricane winds over the Bay of Bengal, 21-25 November	65kt	The system crossed the south-east coast of Bangladesh near Cox's Bazar around noon of 25 November
1996	Cyclonic storm over the Bay of Bengal,12-16 June	45 kt	The system crossed Andhra Pradesh close to Visakhapatnam between 0500 to 0600 UTC of 16/06/1996
1996	Severe cyclonic storm over the Arabian Sea, 17-20 June	55 kt	The system crossed Gujarat coast close to Diu around 2300 UTC on 18 June
1996	Severe cyclonic storm over Arabian Sea, 22-28 October ,1996	Weakened over sea	The system weakened into a well-marked low-pressure area over the east central Arabian Sea and moved westward and dissipated near the Somalia coast/Gulf of Aden by 31 October
1996	Severe cyclonic storm over the Bay of Bengal, 05-07 November	55 kt	The system crossed about 50 km south of Kakinada at 1600 UTC on 06/11/1997.
1996	Severe cyclonic storm with a core of Hurricane winds over Bay of Bengal, 28 November-06 December	45 kt	The system crossed between Chennai and Pondicherry near Mahabalipuram between 1600UTC and 1700UTC on 06 December
1997	Severe cyclonic storm with a core of Hurricane winds over Bay of Bengal, 15-20 May	90kt	The system crossed the Bangladesh coast near Sitakundu at 1430 UTC on 19 May
1997	Severe cyclonic storm over the Bay of Bengal, 23-27 September	55 kt	The system crossed the Bangladesh coast near Hatia at about 2100 UTC of 26 September

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
1997	Severe cyclonic storm Linda over the Bay of Bengal,04-09 November	Weakened over sea	The system weakened rapidly into a well-marked low over the sea.
1998	Severe cyclonic storm over the Bay of Bengal, 17-20 May	60 kt	The system crossed the Bangladesh coast around 0200 UTC between Chittagong and Sitakundu
1998	Very severe cyclonic storm over the Arabian Sea, 4-10 June	80kt	The system crossed the coast near Porbandar between 0100 and 0200 UTC on 09 June
1998	Cyclonic storm over the Arabian Sea, 11-17 October	35 kt	The system crossed the Gujarat coast near Veraval (42909) between 0100 and 0200 UTC of 17 October
1998	Very severe cyclonic storm over the Bay of Bengal, 13-16 November	65 kt	The system crossed the north Andhra Pradesh coast close to Visakhapatnam and south of it between 1100 and 1200 UTC.
1998	Very severe cyclonic storm over the Bay of Bengal, 19-23 November	55 kt	The system crossed the West Bengal coast east of Sagar Island around noon of 22 November
1998	Severe cyclonic storm over the Arabian Sea, 13-17 December 1998	Weakened over sea	The system weakened into a deep depression at 0900 UTC of December 16 and further weakened into a depression over the west central Arabian Sea
1999	Cyclonic storm over Bay of Bengal, 1-3 February	Weakened over sea	Weakened and dissipated over sea
1999	Very severe cyclonic storm over the Arabian Sea, 16-22 May	105 kt	The system crossed the Pakistan coast near the international border in the afternoon of 20 May 1999
1999	Very severe cyclonic storm over the Bay of Bengal, 15-19 October	90 kt	The system crossed the Odisha coast near Gopalpur in the early morning hours of 18 October
1999	Super cyclonic storm over the Bay of Bengal, 25-31 October	140 kt	The system crossed the Odisha coast near Paradip between 0430 and 0630 UTC

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2000	Cyclonic storm over the Bay of Bengal, 27-30 March	Weakened over sea	The system weakened over east-central Bay of Bengal over the sea in the afternoon of 30 March
2000	Cyclonic storm over the Bay of Bengal, 15-19 October	Weakened over sea	The system weakened into a low-pressure area over the sea after 0600 UTC of 19 October 2000
2000	Cyclonic storm over the Bay of Bengal, 25-28 October	35 kt	Crossed Bangladesh coast on 28 October 2000 between 0100 and 0300 UTC near Mongolia
2000	Very severe cyclonic storm over the Bay of Bengal, 26-30 November	77 kt	Crossed Tamil Nadu coast on 29 November 2000 around 1130 UTC near Cuddalore
2000	Very severe cyclonic storm over the Bay of Bengal, 23-28 December	90,55	First land falls near Trincomalee in Sri Lanka on 26 December around 1200 UTC Second landfall near Tuticorinin early morning hours of 28 December 2000 around 2200 UTC
2001	Very Severe Cyclonic storm over the Arabian Sea, 21-28 May	Weakened over sea	The system dissipated over the sea off the Saurashtra coast in the morning of 29 May
2001	Cyclonic storm over the Arabian Sea, 24-27 September	Weakened over sea	The system weakened into a low-pressure area over the sea around 0000 UTC of 28 September
2001	Cyclonic storm over the Arabian Sea, 08-10 October	Weakened over sea	The system weakened into a low-pressure area around 1200 UTC of 10 October
2001	Cyclonic storm over the Arabian Sea, 14-17 October	35 kt	The system crossed the south Andhra Pradesh coast near Nellore around 0000 UTC of 16 October
2002	Cyclonic storm over the Arabian Sea, 06-10, May	35 kt	Crossed Arabian coast near south of Salalah port (Oman) around 0900 UTC on 10 May
2002	Severe cyclonic storm over the Bay of Bengal, 10-12 November	55 kt	Crossed West Bengal coast south of Kolkata near Sagar Island at 0900 UTC of 12 November

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2002	Cyclonic storm over the Bay of Bengal, 23-28 November	Weakened over sea	Weakened into a well-marked low pressure area over the northeast and adjoining east-central Bay of Bengal at 0300 UTC in the night of 28 November
2002	Cyclonic storm over the Bay of Bengal, 21-25 December	Weakened over sea	The system weakened into a low-pressure area over the southwest and adjoining southeast Bay of Bengal after 1500 UTC of 25 December.
2003	Very severe cyclonic storm over the Bay of Bengal, 10-19, May	45 kt	Crossed Myanmar coast north of Kyaukpyu around midnight of 19 May 2003
2003	Severe cyclonic storm over the Arabian Sea, 12-15, November	Weakened over Sea	The system weakened into a low-pressure area on 16th morning and subsequently dissipated over sea off the Somalia coast between 0300 and 0400 UTC.
2003	Severe cyclonic storm over the Bay of Bengal, 11-16 December	55 kt	Crossed the coast near Machilipatnam around 1800UTC of 15 December
2004	Severe cyclonic storm over the Arabian Sea, 05-10 May	Weakened over Sea	Weakened into a low-pressure area over the sea areas of Gujarat coasts in the evening of 10 May
2004	Very severe cyclonic storm over the Bay of Bengal, 16-19 May	90 kt	Crossed Myanmar coast north of Akyab between 0400-0500 UTC of 19 May
2004	Severe cyclonic storm over, Onil, the Arabian Sea, 30 September -03 October	Weakened over sea	Weakened into a well-marked low-presure area over the northeast Arabian Sea off Kutch coast in the morning of 04 October
2004	Severe cyclonic storm, Agni, over the Arabian Sea, 29 November-02 December	Weakened over sea	Weakened into a low-pressure area over the southwest Arabian Sea in the morning of 03 December.
2005	Cyclonic storm, Hibaru, over the Bay of Bengal, 13-17 January	Weakened over Sea	Weakened over the southwest Bay of Bengal and adjoining equatorial Indian Ocean on the night of 17 January

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2005	Cyclonic storm PYARR over the Bay of Bengal, 17-21 September	35kt	Crossed Andhra Pradesh coast near Kalingapatnam (43105) in the morning of 19 September
2005	Cyclonic storm, Baaz, over the Bay of Bengal, 28 November - 02 December	Weakened over sea	Weakened into a well-marked low-presure area over southwest and adjoining west central Bay of Bengal on 02 December 2005 at 0600UTC
2005	Cyclonic storm, Fanoos, over the Bay of Bengal, 06-10 December	35kt	Crossed Tamil Nadu coast close to Vedaranyam (43349) south of Karaikal (43346) at 0530 UTC of 10 December 2005 as a deep depression
2006	Very severe cyclonic storm, Mala, over the Bay of Bengal, 25-29 April	90 kt	The system crossed the Arakan Coast 100 KM south of Sandoway around 0700 UTC of 29 April as very severe cyclonic storm
2006	Severe cyclonic storm, Mukda, over the Arabian Sea, 21- 24 September		The system weakened over the east-cetral Arabian Sea around midnight of 24 September
2006	Cyclonic storm, Ogni over the Bay of Bengal, 29-30 October	30 kt	The system crossed the Andhra Pradesh coast close to Bapatla around 0730 UTC of 30 October as a depression
2007	Cyclonic storm Akash over the Bay of Bengal 13-15 May	45 kt	The system crossed the Bangladesh Coast close to the south of Cox's Bazar near Lat. 21.2°N and Long 92.2°E between 2200 & 2300 UTC on 14 May
2007	Super cyclonic storm Gony over the Arabian Sea 01-07 June	77 kt, 45 kt	The system crossed the northeast Oman coast near Muscat as VSCS between 0200 and 0300 UTC on 06 June. Crossed the Makaran Coast near long 58.0°N as cyclonic storm between 0300 and 0400 UTC of 07 June
2007	Cyclonic storm Yemyin over the Bay of Bengal 25-26 June	35 kt	The system crossed the west coast of Pakistan between 0200-0300 UTC on 26 May

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2007	Very severe cyclonic storm SIDR over the Bay of Bengal, 11-16 November	115 kt	The system crossed the Bangladesh coast around 1700 UTC of 15 November
2008	Very severe cyclonic storm, Nargis, over the Bay of Bengal during 27 April- 3 May,	90 kt	The system crossed the Myanmar Coast between 1200 and 1400 UTC on 02 May
2008	Cyclonic Storm, Rashmi, over the Bay of Bengal during 25-27 October	45kt	The system crossed the Bangladesh coast between 2200-2300 UTC on 26 October
2008	Cyclonic storm, Khaimuk, over the Bay of Bengal during 13-16 November	30 kt	The system crossed the South Andhra Pradesh coast close to the north of Kavali between 2200 and 2300 UTC on 15 November 2008.
2008	Cyclonic storm, Nisha, over the Bay of Bengal during 25-27 November	45 kt	The system crossed Tamil Nadu coast north of Karaikal between 0000 and 0100 UTC of 27 November
2009	Cyclonic Storm, Bijli, over the Bay of Bengal during 14-17 April	25 kt	The system crossed the Bangladesh Coast near 22.2/91.8 close to the south of Chittagong around 1600 UTC on 17 April as a depression
2009	Severe cyclonic storm, Aila, over the Bay of Bengal during 23-26 May	55 kt	The system crossed the West Bengal coast close to Sagar Island between 0800 and 0900 UTC on 25 May
2009	Cyclonic storm, Phyan, over the Arabian Sea during 09-12 November	40 kt	The system crossed the Maharashtra coast between Mumbai and Alibag between 1000 and 1100 UTC on 11 November

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2009	Cyclonic storm Ward, over the Bay of Bengal during 10-15 December	30 kt	The system crossed north Sri Lanka near Trincomalee between 0800 and 0900 UTC of 14 December as deep depression
2010	Severe cyclonic storm Laila, over the Bay of Bengal, 17-21 May	55 kt	The system crossed the Andhra Pradesh coast near Baptala between 1100 and1200 UTC of 20 May,
2010	Cyclonic storm Bandu, over the Arabian Sea, 19-23 May	Weakened over sea	The system weakened into a well-marked low-pressure area over the Gulf of Aden at 0000 UTC of 23 May
2010	Very severe cyclonic storm Phet, over the Arabian Sea, 31 May- 07 June	65 kt, 25 kt	The system crossed the Oman coast between 0000 and 0200 UTC on 4 June 2010 and again crossed the Pakistan coast, close to south of Karachi between 1230 and 1330 UTC on 06 June
2010	Very severe cyclonic Storm Giri, over the Bay of Bengal, 20-23 October	105 kt	The system crossed the Myanmar coast about 70 km east southeast of Sittwe around 1400 UTC of 22 October
2010	Severe cyclonic storm Jal, over the Bay of Bengal, 04-08 November	30 kt	The system crossed north Tamil Nadu and south Andhra Pradesh coast close to north of Chennai near around 1600 UTC on 07 November.
2011	Cyclonic storm Keila, over the Arabian Sea, 29 Octo-ber- 04 November	35 kt	The system crossed the Oman coast close to the north of Salalah (near lat.17.10N and long. 54.30E) between 1600-1700 UTC on 02 November
2011	Very severe cyclonic storm Thane, over the Bay of Bengal, 25-31 December	75 kt	The system crossed the Tamil Nadu coast close to the south of Cuddalore between 0100 and 0200 UTC on 30 December

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2012	Cyclonic storm Murjan over Arabian Sea, 23- 26 October	30 kt	The system crossed the Somalia coast near 9.50N and 50.80E between 1700 and 1800 UTC of 25 October 2012 as a depression
2012	Cyclonic storm, Nilam, over the Bay of Bengal, 28 October 2012 - 01 November 2012	45 kt	The system crossed the north Tamil Nadu coast near Mahabalipuram, south of Chennai (near latitude 12.60N and longtude 80.20E) between 1600 and 1700 hrs. IST of 31 October 2012
2013	Cyclonic storm, Viyaru, over the Bay of Bengal, 10-16 May	45 kt	The system crossed the Bangladesh coast near latitude 22.80 N and longitude 91.40 E, about 30 km south of Feni, around 0800 UTC of 16 May
2013	Very severe cyclonic storm, Phailin, over the Bay of Bengal during 08-14 October	115 kt	Very severe cyclonic storm crossed Odisha and adjoining north Andhra Pradesh coast near Gopalpur around 1700 UTC near 19.20 N and 84.90 E.
2013	Severe cyclonic storm, Helen, over the Bay of Bengal during 19-23 November	55 kt	The system crossed the Andhra Pradesh coast close to south of Machilipatnam near 16.10 N/81.20 E between 0800-0900 UTC of 22 November.
2013	Very severe cyclonic storm, Lehar, over the Bay of Bengal during 23-28 November	55 kt, 30 kt	The system crossed Andaman & Nicobar Island, south of Port Blair, around 0000 UTC on 25 November. The system crossed Andhra Pradesh close to south of Machilipatnam around 0830 UTC on 28 November.
2013	Very severe cyclonic storm, Madi, over the Bay of Bengal during 06-13 December	25 kt	The system crossed the Tamil Nadu coast near Vedaranyamound 1330 UTC and merged into Palk Strat and again crossed the Tamil Nadu coast near Tondi around 1700 UTC on 12 December.

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2014	Cyclonic storm Nanauk over the Arabian Sea (10-14 June	Weakened over sea	Weakened into a well-marked low-pressure area over the northwest and adjoining west central Arabian Sea at 0300 UTC 14 June
2014	Very severe cyclonic storm Hudhud, over the Bay of Bengal, 07-14 October	100 kt	The system crossed Andaman & Nicobar Island near Long Island (near lat.12.4 0N and long. 92.90E) between 0300-0400 UTC on 08 October, and it again crossed the Andhra Pradesh coast over Visakhapatnam between 0630 and 0730 UTC on 12 October as very severe cyclonic storm
2014	Very severe cyclonic storm Nilofar over the Arabian Sea, 25-31 October	Weakened over sea	The system weakened into a well-marked low-pressure area over the northeast Arabian Sea off the north Gujarat coast at 0300 UTC on 31 October
2015	Cyclonic storm Ashobaa, over the Arabian Sea, 07-12 June	Weakened over sea	The system weakened into a well-marked low pressure over the northwest Arabian Sea and adjoining Oman coast at 1200 UTC on 12 June
2015	Cyclonic storm, Komen, over the Bay of Bengal, 26 July–2 August	35 kt	The system crossed the Bangladesh coast near longitude 91.40°E during 1400-1500 UTC on 30 July 2015
2015	Extremely severe cyclonic storm Chapala, over the Arabian Sea, 28 October to 04 November	65 kt	The system crossed the Yemen coast to the southwest of Riyan (14.1/48.65) between 0100 and 0200 UTC of 3 November as very severe cyclonic storm
2015	Extremely severe cyclonic storm Megh over the Arabian Sea, 05-10 November	30 kt	The system crossed the Yemen coast (13.4/46.1) at 0900 UTC of 10 November as a Deep Depression (DD)

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2016	Cyclonic storm, Roanu, over the Bay of Bengal, 17-22 May	45 kt	The system crossed the southeast coast of Bangladesh near latitude 22.60°N and longitude 91.60°E around 1000 UTC of 21/05/2016 as cyclonic storm
2016	Cyclonic storm, Kyant, over the Bay of Bengal, (21-28 October)	Weakened over sea	The system weakened into a well-marked low-pressure area over west central Bay of Bengal off the Andhra Pradesh coast at 0000 UTC on 28 October
2016	Cyclonic storm, Nada, over the Bay of Bengal, 29 November-02 December	25 kt	The system crossed the north Tamil Nadu coast near Nagapattinam (latitude 10.750°N and longitude 79.90°E) between 2230 and 2330 UTC of 01 December as a depression
2016	Very severe cyclonic storm, Vardah, over the Bay of Bengal, 06-13 December	60 kt	Crossed the north Tamil Nadu coast close to Chennai near 13.130N/80.30E during 0930-1130 UTC on 12 December
2017	Cyclonic storm, Maarutha, over the Bay of Bengal, 15-17 April	40 kt	Crossed the Myanmar coast near Sandoway (Thandwe) near 18.4N/94.3E during 1800-1900 UTC of 16 April
2017	Severe cyclonic storm, Mora, over the Bay of Bengal, 28-31 May	60 kt	Crossed the Bangladesh coast close to the south of Chittagong near 22.0 N/91.9E during 0400-0500 UTC
2017	Very severe cyclonic storm, Ockhi, over the Bay of Bengal, 29 November–06 December	20 kt	Weakened into a well-marked low-pressure area over northeast Arabian Sea and adjoining east and central Arabian Sea, south coastal Gujarat and north coastal Maharashtra at 2100 UTC of 5 December
2018	Cyclonic storm, Sagar, over the Arabian Sea, 16-21 May	40 kt	Crossed the Somalia coast near latitude 10.650N/44.00E between 0800 and 0900 UTC

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2018	Extremely severe cyclonic storm, Mekunu, over the Arabian Sea, 21–27 May	95 kt	Crossed south Oman coast near latitude 16.85N and longitude 53.75°E during 1830 UTC and 1930UTC of 25 May
2018	Cyclonic storm, Daye, over the Bay of Bengal, 19–22 September	35 kt	Crossed south Odisha and adjoining north Andhra Pradesh coasts close to Gopalpur near 19.27N/84.92E between 1900 and 2000 UTC on 20 September
2018	Very severe cyclonic storm, Luban, over the Arabian Sea, 06–15 October	40 kt	Crossed Yemen and adjoining Oman coasts near 15.80N and 52.20E from 0530 to 0600 UTC
2018	Very severe cyclonic storm, Titli," over east and central Bay of Bengal, 08-13 October	80 kt	Crossed north Andhra Pradesh and south Odisha coasts near 18.80N/84.50E during 2300 UTC of 10 October and -0000 UTC of 11 October
2018	Very severe cyclonic storm, Gaja, over east and central Bay of Bengal, 10-19 November	70 kt	Crossed the Tamil Nadu and Puducherry coasts between Nagapattinam and Vedaranniyam near 10.450N and 79.80E from 1900 to 2100 UTC
2018	Severe cyclonic storm, Phethai, over southeast Bay of Bengal, 13–18 December	45 kt	Crossed the Andhra Pradesh coast near 16.550N and 82.250E 25 km south of Yanam and 40 km south of Kakinada from 0800 to 0900 UTC
2019	Cyclonic storm, Pabuk, over the Andaman Sea, 04-08 January	30 kt	Crossed Andaman Islands near 11.6°N/92.7°E, close to the south of Port Blair between 1300 and 1500 UTC on 6 January
2019	Extremely severe cyclonic storm, Fani, over east and central equatorial Indian Ocean and adjoining southeast Bay of Bengal, 26 April–04 May	100 kt	Crossed the Odisha coast close to Puri (near latitude 19.750N and longitude 85.70E between 0230 and 0430 UTC of 3 May

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2019	Very severe cyclonic storm, Vayu, over the Arabian Sea, 10–17 June	20 kt	Weakened into a WML over northeast AS and adjoining areas of Saurashtra and Kutch
2019	Very severe cyclonic storm, Hikaa, over east, central and adjoining northeast Arabian Sea, 22–25 September	75 kt	Crossed the Oman coast near latitude 19.7 N and longitude 57.7 E between 1400 UTC and 1500 UTC on 24 September
2019	Super cyclonic storm, Kyarr, over the Arabian Sea, 24 October–02 November	20 kt	Weakened into a well-marked low-pressure area over the west, central and adjoining southwest Arabian Sea off the North Somalia coast
2019	Extremely severe cyclonic storm, Maha, over the Arabian Sea, 30th October–07th November	20 kt	Weakened into a well-marked low-pressure area over the northeast Arabian Sea and adjoining south Gujarat coast
2019	Very severe cyclonic storm, Bul Bul, over the Bay of Bengal, 05th–11th November	60 kt	Crossed the West Bengal coast close to Sunderban Dhanchi forest near 21.55°N/88.5°E from 1500 to 1800 UTC on 9 November
2019	Cyclonic storm, Pawan, over the southwest Arabian Sea and adjoining equatorial Indian Ocean, 02–07 December	35 kt	Crossed the Somalia coast near latitude 7.4°N and longitude 49.6°E during 0200 to 0300 UTC of 7 December
2020	Super cyclonic storm, Amphan, over the southeast Bay of Bengal, 16-21 May	90 kt	Crossed the West Bengal–Bangladesh coasts as a very severe cyclonic storm across Sundarbans, near lat.21.65°N/long. 88.3°E during1000-1200 UTC, with a maximum sustained wind speed of 85 knots gusting to 100 knots

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2020	Severe cyclonic storm, Nisarga, over the east, central and adjoining southeast Arabian Sea, 01-04 June	60 kt	Crossed the Maharashtra coast close to the south of Alibag near 18.35^{0}N/72.95^{0}E, as severe cyclonic storm with a maximum sustained wind speed of 60 kt gusting to 70 kt between 0700-0900 UTC of 03 June

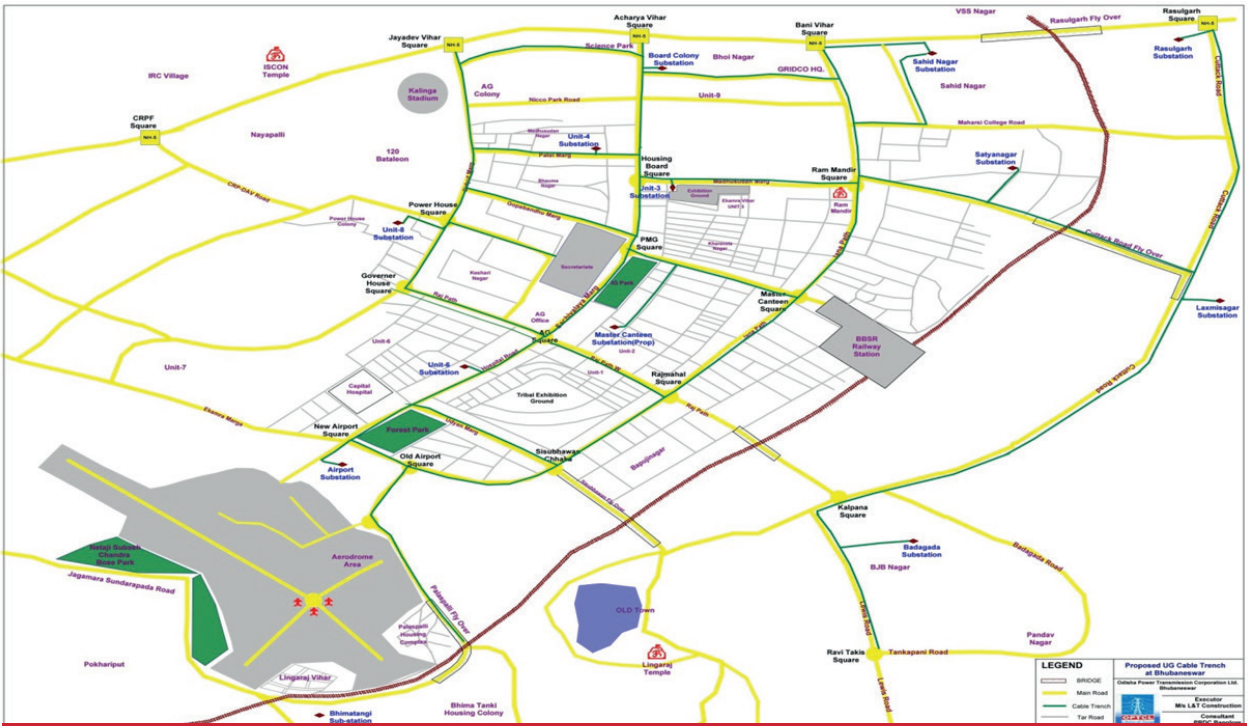
Annexure 3: Cyclone Parameters for Districts (Touching the Coast)

State	Districts	No. of Severe Cyclones	Total No. of Cyclones	Wind Speed (in knots)	PMSS (in m)	PMP (in cm)
West Bengal	South24 Parganas	16	29	115	12	52
	Medinipur	10	22	115	13	56
Odisha	Balasore	5	28	75	11	60
	Kendrapara	6	17	140	8.5	60
	Bhadrak	4	17	65	9.5	60
	Jagatsinghpur	4	17	140	6.5	60
	Ganjam	5	11	100	4	48
	Puri	1	6	140	4	60
	Khordha	0	4	100	4	52
Andhra Pradesh	Nellore	8	18	110	4.5	60
	East Godavari	4	17	125	4.5	52
	Srikakulam	5	12	100	4	56
	Guntur	0	0	127	7.5	56
	Visakhapatnam	4	8	125	4	52
	Krishna	5	12	127	5.5	56
	West Godavari	3	6	127	5	52
	Prakasam	3	5	115	6	52
	Vizianagaram	1	3	94	4	52
Tamil Nadu	Pudukkottai	1	1	55	7	52
	Kanchipuram	8	13	55	3.5	68
	Cuddalore	4	6	90	3.5	68
	Tiruvarur	3	6	90	5.5	60
	Nagappattinam	3	10	90	4.5	68
	Chennai	0	0	95	3.5	52
	Viluppuram	3	3	77	3.5	68
	Ramanathapura m	1	2	55	12	48
	Thoothukudi	1	1	55	7	52
	Tirunelveli	3	3	55	7	48
	Thanjavur	1	2	90	5.5	48
	Tiruvallur	0	5	95	4	56

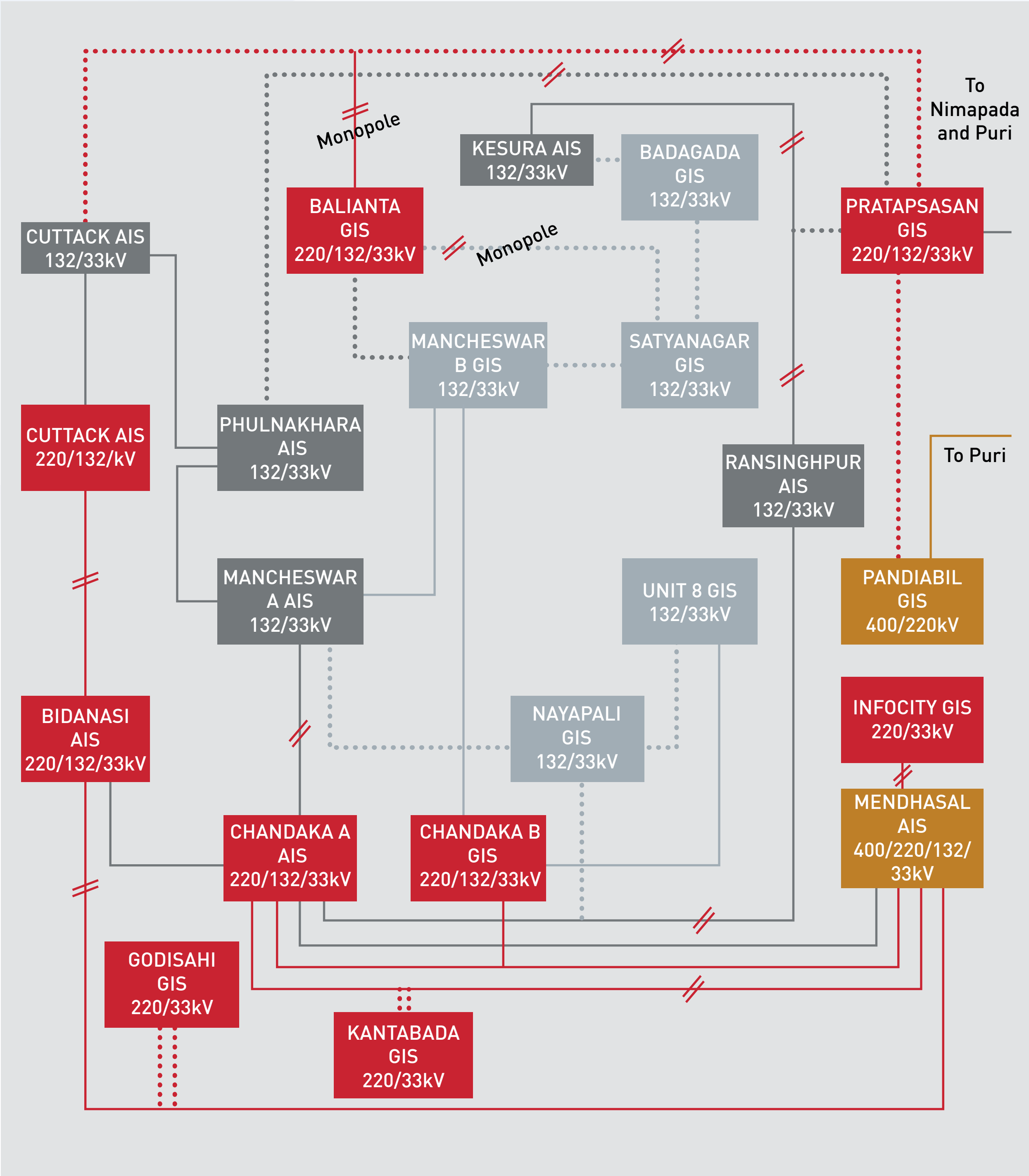
	Kanyakumari	0	0	45	3	40
Puducherry	Puducherry	3	3	77	3.5	68
	Karaikal	3	10	90	4.5	52
	Yanam	4	17	125	4.5	52
Andaman and Nicobar Islands	Andaman and Nicobar Islands	1	8	90	–	N/A

PMSS: Probable Maximum Storm Surge
PMP: Probable Maximum Precipitation"

Annexure 4: Map showing UG Cabling Route in Bhubaneswar City



Annexure 5: UG Cabling Route in Bhubaneswar City



Annexure 6: Pictures of Distribution Transformer Failure

Annexure 7: Disaster Management Policies Across the Globe

Most countries have their own strategies to mitigate various disasters and have framed policies accordingly. However, their policies are more likely to be similar to ours. The following countries have set up their own disaster management plan and policies to tackle various disasters.

A7.1. Brazil

Disaster response in Brazil is highly decentralized and proceeds from the bottom up with minimal coordination from the national government. In the event of a natural disaster, the affected municipality handles its own response. When the scope of the disaster exceeds the municipality's capacity to respond, the regional office is called in, followed by the state and then the national level. This separation of powers is attributed to the Brazilian legal structure, which ascribes a great deal of autonomy to the state and local governments. At the national level, the disaster management plan is known as the National Civil Defence System (SINDEC). Coordination of SINDEC falls to the National Secretariat of Civil Defence (SEDEC), which is connected to a branch of the Ministry of National Integration.

A7.2. Australia

The Australian emergency management sector is one of the country's most decentralized aspects of government. It relies heavily on trust and the relationships between the federal, state and local governments.

A7.3. Netherlands

In the Netherlands, the Ministry of Security and Justice is responsible for emergency preparedness and emergency management on a national level and operates a national crisis centre (NCC). The country is divided into 25 safety regions. In a safety region, there are four components: the regional fire department, the regional department for medical care (ambulances, psycho-sociological care), the regional despatch and a section for risk and crisis management. The regional despatch operates for the police, fire department and regional medical care. The despatch combines all these three services into one for the best multi-coordinated response to an incident or an emergency. It also facilitates information management, emergency communication and care of citizens. All regions operate according to the coordinated regional incident management system.

A7.4. USA:

In the USA, because of geographical differences, various threats affect communities in the states. Thus, although similarities may exist, all disaster management plans will be completely different. This creates a more resilient plan for unique events because all common processes are defined and it encourages planning done by the stakeholders who are closer to the individual processes. In the United States, all disasters are initially local, with local authorities, usually the police, fire, or EMS agency, taking charge.

If the event becomes overwhelming to local government, state emergency management (the primary government structure of the USA) becomes the controlling emergency management agency. Federal Emergency Management Agency (FEMA), part of the Department of Homeland Security (DHS), is the lead federal agency for emergency management. The USA and its territories are divided into ten regions for FEMA's emergency management purposes. FEMA supports but does not override state authority.

A7.5. Japan

Disaster management in Japan is vested in a three-layered system: national, prefectural and municipal layers. The disaster management system of Japan has undergone tremendous advancement throughout the past five to six decades. Disaster management councils are established at each level and each council is responsible for implementing all disaster management-related issues under its authority.

Central Disaster Management Council (CDMC) consists of the prime minister, who is the chairperson, the minister of state for disaster management, all ministers, heads of major public institutions and experts. The council promotes comprehensive disaster countermeasures, including deliberating important issues on disaster reduction according to requests from the prime minister or minister of state for disaster management. The duties of the council include formulating and promoting implementation of the basic disaster management plan and earthquake countermeasures plans, formulating and promoting implementation of the urgent measures plan for major disasters, deliberating important issues on disaster reduction according to requests from the prime minister or minister of state for disaster management (basic disaster management policies, overall coordination of disaster countermeasures and declaration of state of disaster emergency) and offering opinions regarding important issues on disaster reduction to the prime minister and minister of state for disaster management.

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Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2014	Cyclonic storm Nanauk over the Arabian Sea (10-14 June	Weakened over sea	Weakened into a well-marked low-pressure area over the northwest and adjoining west central Arabian Sea at 0300 UTC 14 June
2014	Very severe cyclonic storm Hudhud, over the Bay of Bengal, 07-14 October	100 kt	The system crossed Andaman & Nicobar Island near Long Island (near lat.12.4 0N and long. 92.90E) between 0300-0400 UTC on 08 October, and it again crossed the Andhra Pradesh coast over Visakhapatnam between 0630 and 0730 UTC on 12 October as very severe cyclonic storm
2014	Very severe cyclonic storm Nilofar over the Arabian Sea, 25-31 October	Weakened over sea	The system weakened into a well-marked low-pressure area over the northeast Arabian Sea off the north Gujarat coast at 0300 UTC on 31 October
2015	Cyclonic storm Ashobaa, over the Arabian Sea, 07-12 June	Weakened over sea	The system weakened into a well-marked low pressure over the northwest Arabian Sea and adjoining Oman coast at 1200 UTC on 12 June
2015	Cyclonic storm, Komen, over the Bay of Bengal, 26 July–2 August	35 kt	The system crossed the Bangladesh coast near longitude 91.40°E during 1400-1500 UTC on 30 July 2015
2015	Extremely severe cyclonic storm Chapala, over the Arabian Sea, 28 October to 04 November	65 kt	The system crossed the Yemen coast to the southwest of Riyan (14.1/48.65) between 0100 and 0200 UTC of 3 November as very severe cyclonic storm
2015	Extremely severe cyclonic storm Megh over the Arabian Sea, 05-10 November	30 kt	The system crossed the Yemen coast (13.4/46.1) at 0900 UTC of 10 November as a Deep Depression (DD)

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2016	Cyclonic storm, Roanu, over the Bay of Bengal, 17-22 May	45 kt	The system crossed the southeast coast of Bangladesh near latitude 22.60°N and longitude 91.60°E around 1000 UTC of 21/05/2016 as cyclonic storm
2016	Cyclonic storm, Kyant, over the Bay of Bengal, (21-28 October)	Weakened over sea	The system weakened into a well-marked low-pressure area over west central Bay of Bengal off the Andhra Pradesh coast at 0000 UTC on 28 October
2016	Cyclonic storm, Nada, over the Bay of Bengal, 29 November-02 December	25 kt	The system crossed the north Tamil Nadu coast near Nagapattinam (latitude 10.750°N and longitude 79.90°E) between 2230 and 2330 UTC of 01 December as a depression
2016	Very severe cyclonic storm, Vardah, over the Bay of Bengal, 06-13 December	60 kt	Crossed the north Tamil Nadu coast close to Chennai near 13.130N/80.30E during 0930-1130 UTC on 12 December
2017	Cyclonic storm, Maarutha, over the Bay of Bengal, 15-17 April	40 kt	Crossed the Myanmar coast near Sandoway (Thandwe) near 18.4N/94.3E during 1800-1900 UTC of 16 April
2017	Severe cyclonic storm, Mora, over the Bay of Bengal, 28-31 May	60 kt	Crossed the Bangladesh coast close to the south of Chittagong near 22.0 N/91.9E during 0400-0500 UTC
2017	Very severe cyclonic storm, Ockhi, over the Bay of Bengal, 29 November–06 December	20 kt	Weakened into a well-marked low-pressure area over northeast Arabian Sea and adjoining east and central Arabian Sea, south coastal Gujarat and north coastal Maharashtra at 2100 UTC of 5 December
2018	Cyclonic storm, Sagar, over the Arabian Sea, 16-21 May	40 kt	Crossed the Somalia coast near latitude 10.650N/44.00E between 0800 and 0900 UTC

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2018	Extremely severe cyclonic storm, Mekunu, over the Arabian Sea, 21–27 May	95 kt	Crossed south Oman coast near latitude 16.85N and longitude 53.75°E during 1830 UTC and 1930UTC of 25 May
2018	Cyclonic storm, Daye, over the Bay of Bengal, 19–22 September	35 kt	Crossed south Odisha and adjoining north Andhra Pradesh coasts close to Gopalpur near 19.27N/84.92E between 1900 and 2000 UTC on 20 September
2018	Very severe cyclonic storm, Luban, over the Arabian Sea, 06–15 October	40 kt	Crossed Yemen and adjoining Oman coasts near 15.80N and 52.20E from 0530 to 0600 UTC
2018	Very severe cyclonic storm, Titli," over east and central Bay of Bengal, 08-13 October	80 kt	Crossed north Andhra Pradesh and south Odisha coasts near 18.80N/84.50E during 2300 UTC of 10 October and -0000 UTC of 11 October
2018	Very severe cyclonic storm, Gaja, over east and central Bay of Bengal, 10-19 November	70 kt	Crossed the Tamil Nadu and Puducherry coasts between Nagapattinam and Vedaranniyam near 10.450N and 79.80E from 1900 to 2100 UTC
2018	Severe cyclonic storm, Phethai, over southeast Bay of Bengal, 13–18 December	45 kt	Crossed the Andhra Pradesh coast near 16.550N and 82.250E 25 km south of Yanam and 40 km south of Kakinada from 0800 to 0900 UTC
2019	Cyclonic storm, Pabuk, over the Andaman Sea, 04-08 January	30 kt	Crossed Andaman Islands near 11.6°N/92.7°E, close to the south of Port Blair between 1300 and 1500 UTC on 6 January
2019	Extremely severe cyclonic storm, Fani, over east and central equatorial Indian Ocean and adjoining southeast Bay of Bengal, 26 April–04 May	100 kt	Crossed the Odisha coast close to Puri (near latitude 19.750N and longitude 85.70E between 0230 and 0430 UTC of 3 May

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2019	Very severe cyclonic storm, Vayu, over the Arabian Sea, 10–17 June	20 kt	Weakened into a WML over northeast AS and adjoining areas of Saurashtra and Kutch
2019	Very severe cyclonic storm, Hikaa, over east, central and adjoining northeast Arabian Sea, 22–25 September	75 kt	Crossed the Oman coast near latitude 19.7 N and longitude 57.7 E between 1400 UTC and 1500 UTC on 24 September
2019	Super cyclonic storm, Kyarr, over the Arabian Sea, 24 October–02 November	20 kt	Weakened into a well-marked low-pres- sure area over the west, central and adjoining southwest Arabian Sea off the North
2019	Extremely severe cyclonic storm, Maha, over the Arabian Sea, 30th October–07th November	20 kt	Somalia coast Weakened into a well-marked low-pres- sure area over the northeast Arabian Sea and adjoining south Gujarat coast
2019	Very severe cyclonic storm, Bul Bul, over the Bay of Bengal, 05th–11th November	60 kt	Crossed the West Bengal coast close to Sunderban Dhanchi forest near 21.55°N/88.5°E from 1500 to 1800 UTC
2019	Cyclonic storm, Pawan, over the southwest Arabi- an Sea and adjoining equatorial Indian Ocean, 02–07 December	35 kt	on 9 November Crossed the Somalia coast near latitude 7.4°N and longitude 49.6°E during 0200 to 0300 UTC of 7 December
2020	Super cyclonic storm, Amphan, over the southeast Bay of Bengal, 16-21 May	90 kt	Crossed the West Bengal–Bangladesh coasts as a very severe cyclonic storm across Sundarbans, near lat.21.65°N/long. 88.3°E during1000-1200 UTC, with a

Year	Cyclone	Maximum Sustained Wind (MSW) at the Time of Landfall	Landfall Place and Time
2020	Severe cyclonic storm, Nisarga, over the east, central and adjoining southeast Arabian Sea, 01-04 June	60 kt	Crossed the Maharashtra coast close to the south of Alibag near 18.35°N/72.95°E, as severe cyclonic storm with a maximum sustained wind speed of 60 kt gusting to 70 kt between 0700-0900 UTC of 03 June

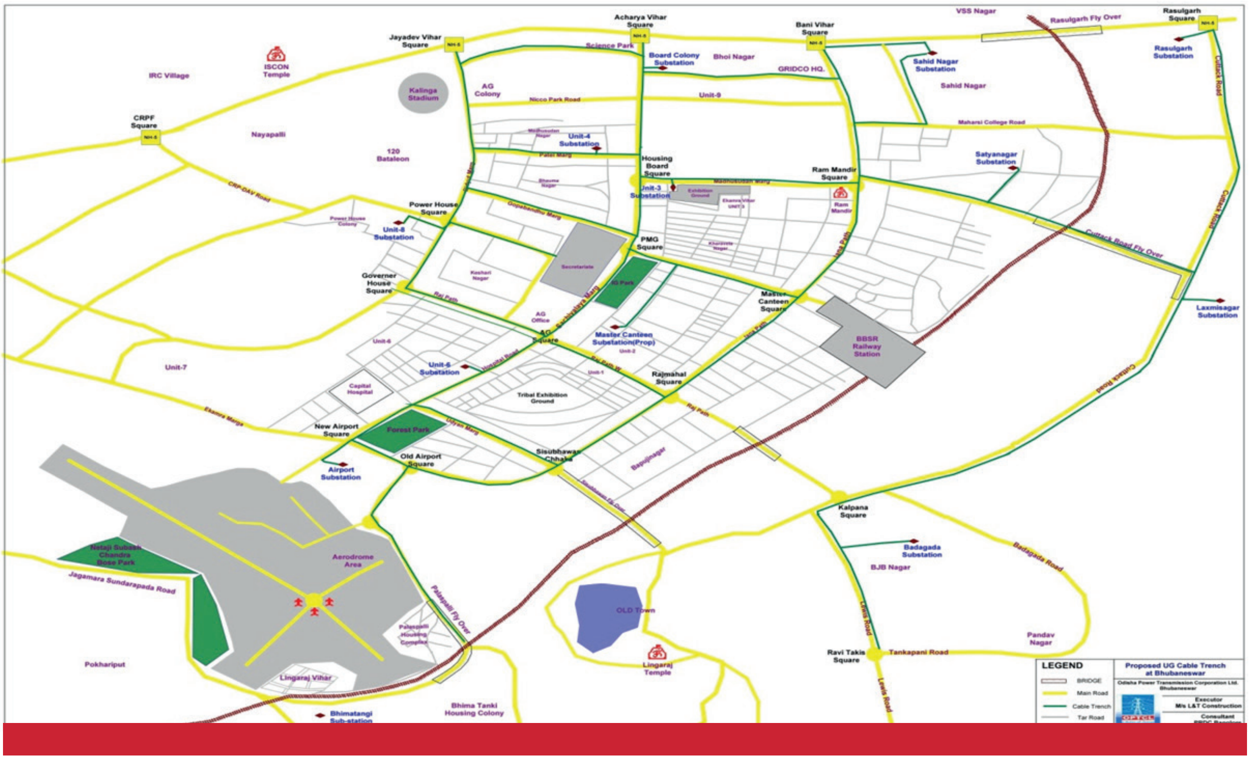
Annexure 3: Cyclone Parameters for Districts (Touching the Coast)

State	Districts	No. of Severe Cyclones	Total No. of Cyclones	Wind Speed (in knots)	PMSS (in m)	PMP (in cm)
West Bengal	South24 Parganas	16	29	115	12	52
	Medinipur	10	22	115	13	56
Odisha	Balasore	5	28	75	11	60
	Kendrapara	6	17	140	8.5	60
	Bhadrak	4	17	65	9.5	60
	Jagatsinghpur	4	17	140	6.5	60
	Ganjam	5	11	100	4	48
	Puri	1	6	140	4	60
	Khordha	0	4	100	4	52
Andhra Pradesh	Nellore	8	18	110	4.5	60
	East Godavari	4	17	125	4.5	52
	Srikakulam	5	12	100	4	56
	Guntur	0	0	127	7.5	56
	Visakhapatnam	4	8	125	4	52
	Krishna	5	12	127	5.5	56
	West Godavari	3	6	127	5	52
	Prakasam	3	5	115	6	52
	Vizianagaram	1	3	94	4	52
Tamil Nadu	Pudukkottai	1	1	55	7	52
	Kanchipuram	8	13	55	3.5	68
	Cuddalore	4	6	90	3.5	68
	Tiruvarur	3	6	90	5.5	60
	Nagappattinam	3	10	90	4.5	68
	Chennai	0	0	95	3.5	52
	Viluppuram	3	3	77	3.5	68
	Ramanathapura m	1	2	55	12	48
	Thoothukudi	1	1	55	7	52
	Tirunelveli	3	3	55	7	48
	Thanjavur	1	2	90	5.5	48
	Tiruvallur	0	5	95	4	56

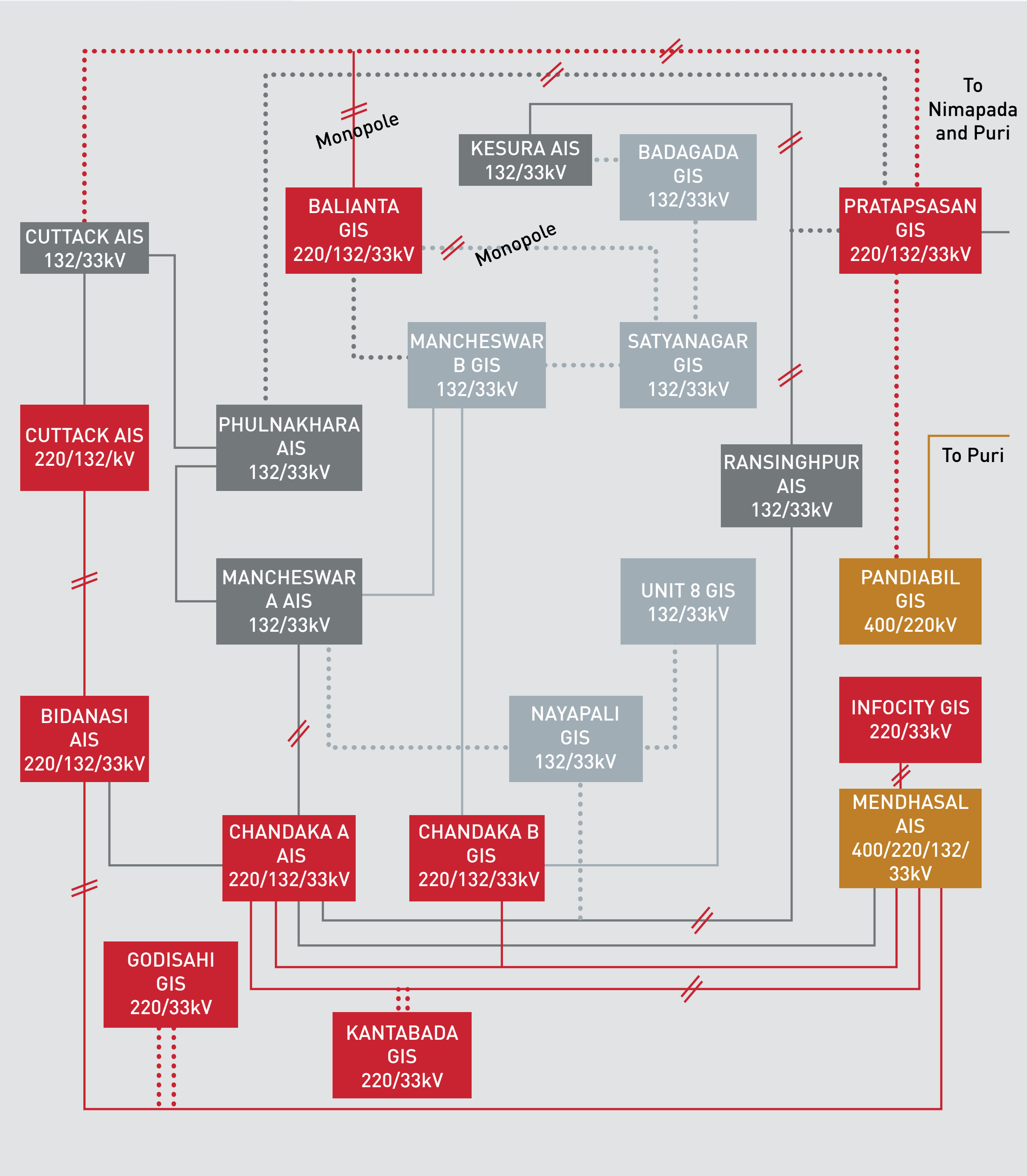
	Kanyakumari	0	0	45	3	40
Puducherry	Puducherry	3	3	77	3.5	68
	Karaikal	3	10	90	4.5	52
	Yanam	4	17	125	4.5	52
Andaman and Nicobar Islands	Andaman and Nicobar Islands	1	8	90	–	N/A

PMSS: Probable Maximum Storm Surge
PMP: Probable Maximum Precipitation"

Annexure 4: Map showing UG Cabling Route in Bhubaneswar City



Annexure 5: UG Cabling Route in Bhubaneswar City



Annexure 6: Pictures of Distribution Transformer Failure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Annexure 7: Disaster Management Policies Across the Globe

Most countries have their own strategies to mitigate various disasters and have framed policies accordingly. However, their policies are more likely to be similar to ours. The following countries have set up their own disaster management plan and policies to tackle various disasters.

A7.1. Brazil

Disaster response in Brazil is highly decentralized and proceeds from the bottom up with minimal coordination from the national government. In the event of a natural disaster, the affected municipality handles its own response. When the scope of the disaster exceeds the municipality's capacity to respond, the regional office is called in, followed by the state and then the national level. This separation of powers is attributed to the Brazilian legal structure, which ascribes a great deal of autonomy to the state and local governments. At the national level, the disaster management plan is known as the National Civil Defence System (SINDEC). Coordination of SINDEC falls to the National Secretariat of Civil Defence (SEDEC), which is connected to a branch of the Ministry of National Integration.

A7.2. Australia

The Australian emergency management sector is one of the country's most decentralized aspects of government. It relies heavily on trust and the relationships between the federal, state and local governments.

A7.3. Netherlands

In the Netherlands, the Ministry of Security and Justice is responsible for emergency preparedness and emergency management on a national level and operates a national crisis centre (NCC). The country is divided into 25 safety regions. In a safety region, there are four components: the regional fire department, the regional department for medical care (ambulances, psycho-sociological care), the regional despatch and a section for risk and crisis management. The regional despatch operates for the police, fire department and regional medical care. The despatch combines all these three services into one for the best multi-coordinated response to an incident or an emergency. It also facilitates information management, emergency communication and care of citizens. All regions operate according to the coordinated regional incident management system.

A7.4. USA:

In the USA, because of geographical differences, various threats affect communities in the states. Thus, although similarities may exist, all disaster management plans will be completely different. This creates a more resilient plan for unique events because all common processes are defined and it encourages planning done by the stakeholders who are closer to the individual processes. In the United States, all disasters are initially local, with local authorities, usually the police, fire, or EMS agency, taking charge.

If the event becomes overwhelming to local government, state emergency management (the primary government structure of the USA) becomes the controlling emergency management agency. Federal Emergency Management Agency (FEMA), part of the Department of Homeland Security (DHS), is the lead federal agency for emergency management. The USA and its territories are divided into ten regions for FEMA's emergency management purposes. FEMA supports but does not override state authority.

A7.5. Japan

Disaster management in Japan is vested in a three-layered system: national, prefectural and municipal layers. The disaster management system of Japan has undergone tremendous advancement throughout the past five to six decades. Disaster management councils are established at each level and each council is responsible for implementing all disaster management-related issues under its authority.

Central Disaster Management Council (CDMC) consists of the prime minister, who is the chairperson, the minister of state for disaster management, all ministers, heads of major public institutions and experts. The council promotes comprehensive disaster countermeasures, including deliberating important issues on disaster reduction according to requests from the prime minister or minister of state for disaster management. The duties of the council include formulating and promoting implementation of the basic disaster management plan and earthquake countermeasures plans, formulating and promoting implementation of the urgent measures plan for major disasters, deliberating important issues on disaster reduction according to requests from the prime minister or minister of state for disaster management (basic disaster management policies, overall coordination of disaster countermeasures and declaration of state of disaster emergency) and offering opinions regarding important issues on disaster reduction to the prime minister and minister of state for disaster management.

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